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EXPERIMENTAL CARDIAC VALVULAR DISEASE IN DOGS, AND SUBACUTE AND CHRONIC CARDIAC VALVULAR DISEASE IN MAN

A COMPARATIVE PATHOLOGIC STUDY *

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In a previous paper [1] a method was presented for creating cardiac valvular disease in dogs. The purpose of the present study is to compare the gross and microscopic structures of these experimental canine lesions with the lesions of subacute and chronic cardiac valvular disease in man.

The contention has been advanced by Swift [2] and others that the vegetations of subacute bacterial endocarditis are engrafted on abnormal valves and, in the majority of instances, on valves that have been the site of rheumatic endocarditis. By the method previously described,[1] similar vegetations may be implanted on artificially traumatized valves in dogs. The chronological development of the two lesions in each case is reversed, however. In man, some form of valvular disease appears to be essential before vegetative endocarditis may occur. In dogs, fibrosis and cicatrization take place as the lesions of acute vegetative endocarditis heal.

Although the etiology of rheumatic mitral stenosis is quite different from that of experimental stenosis, in both gross and microscopic pathology, the two lesions are somewhat comparable.

METHOD

Under ether anesthesia administered intratracheally by the Erlanger respiratory apparatus, the heart was exposed by subperiosteal resection of a portion of the left fifth rib. The electrode of a diathermy unit delivering a high frequency, bipolar current was introduced into the chamber of the left ventricle through the anterior wall. When the tip of the instrument was accurately approximated to the inferior surface of the leaflets of the mitral valve, the current was applied. When the

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1. Powers, J. H.: The Experimental Production of Mitral Stenosis, Arch. Surg. **18**:1945 (April) 1929.

2. Swift, H. F.: The Heart in Infection, Am. Heart J. **3**:629, 1928.

valve had been adequately traumatized, the instrument was withdrawn and the wounds were closed.

Fifty-seven operations were performed. The total operative mortality was 33.3 per cent. Eight dogs were not inoculated. Subsequent examination of the hearts of these animals showed small, fibrous scars at the site of coagulation, but no thickening of the leaflets of the valve and no stenosis of the orifice.

Five dogs were inoculated intravenously with cultures of *Streptococcus cardioarthritidis*.[3] The remaining animals received cultures of *Streptococcus viridans*. All but two[4] developed evidence of acute vegetative endocarditis on the traumatized valve. If the acute process subsided, the leaflets became thickened and fibrosed; dense, cartilaginous scars formed around the base of the mitral ring, and frequently a real stenosis of the orifice was apparent.

Into several normal dogs were injected cultures of *Streptococcus viridans* for the purpose of control studies. When the hearts were subsequently examined, no evidence of endocarditis was found.

From the experimental material thus obtained, three hearts have been selected to demonstrate the gross and microscopic structure of these lesions. From a large number of human hearts[5] that were studied, two have been chosen to illustrate the comparative pathologic changes.

PRESENTATION OF MATERIAL

Experimental Lesions.—Dog B-30.—Electrocoagulation of the mitral valve was performed under ether anesthesia. On the third postoperative day no murmur was audible. The dog was inoculated intravenously with 20 cc. of a broth culture of *Streptococcus viridans*. Two days later a harsh, blowing systolic murmur was audible. The dog was injected with 80 cc. of a similar culture. The following day a blood culture was taken, and *Streptococcus viridans* was obtained. The animal was killed one week after the first inoculation and the heart was removed immediately.

Gross Description: The heart was normal in size and consistency. The pericardium was adherent over the anterolateral border of the left ventricle at the site of the recent operative incision. No thrombi were present and with the exception of the wound in the left ventricle, no myocardial abnormalities were apparent.

The aortic, pulmonic and tricuspid valves were normal.

Almost completely encircling the mitral valve was a rim of grayish, translucent, warty vegetations from 1 to 3 mm. in diameter (fig. 1). These lesions were friable, though firmly attached to the segments of the valve just above their free

3. Small, J. C.: The Bacterium Causing Rheumatic Fever and a Preliminary Account of Its Specific Antiserum, Am. J. M. Sc. **173**:101, 1927.

4. When the hearts of these two animals were examined post mortem it was evident that the electrode had been passed through the mitral orifice and placed in contact with the endocardium of the left auricle. The leaflets of the mitral valve were normal.

5. The author is greatly indebted to the Department of Pathology of the Peter Bent Brigham Hospital for the opportunity of examining these specimens and for valuable assistance in the interpretation of his observations.

margins. On cross-section there was no fibrosis of the segments and no thickening except where the incision passed through a vegetation. The orifice of the valve admitted the tip of the little finger.

Microscopic Description: The sections were stained with hematoxylin and eosin, Giemsa and Goodpasture stains. The section included a small portion of both the auricular and the ventricular walls and a complete segment of the mitral valve. Except for some edema of the auricular wall, the myocardium of both auricle and ventricle was normal. As it approached the mitral valve, the endocardium became thickened, and a pronounced cellular response was evident in an area of considerable size at the base of the leaflet. This cellular infiltration extended for some distance along the subendocardium of the ventricle and consisted almost entirely of polymorphonuclear leukocytes. On the ventricular aspect of the base of the valve was a superficial area of myocardial necrosis with early fibroblastic proliferation into the periphery. Hemosiderin was quite prominent. A considerable amount of hemorrhage was present.

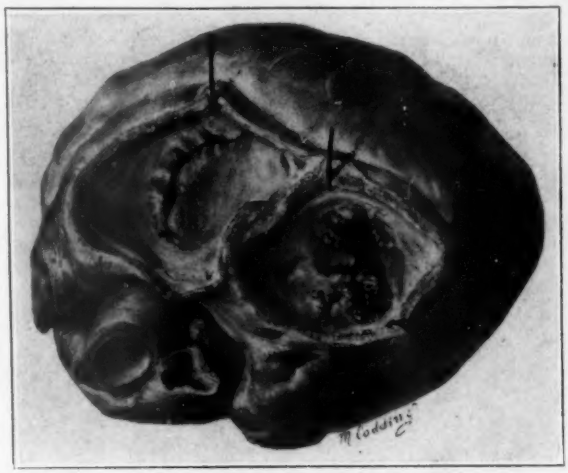

Fig. 1.—Experimental vegetative endocarditis produced by electrocoagulation of the mitral valve and intravenous inoculation with cultures of Streptococcus viridans in dog B-30. The animal was killed one week after the first inoculation.

The mitral valve itself was greatly altered. From the widened valvular base, which was heavily infiltrated with polymorphonuclear leukocytes and in which areas of necrosis were visible (fig. 2), the valve approached more normal thickness until the distal half was reached. Here the endocardium was almost replaced by a large thrombus. Only a few strands of necrotic fibrous tissue were apparent. A heavy infiltration of polymorphonuclear leukocytes had occurred into the remaining substance of the valve.

While a considerable portion of the degenerative changes in the valve was probably due to coagulation, there were numerous thrombi with large numbers of inflammatory cells which were characteristic of bacterial injury. In fact, examination of identical sections through the valve of another heart revealed several clumps of bacteria embedded in the thrombi (fig. 3).

Dog B-19.—Electrocoagulation of the mitral valve was performed with the dog under ether anesthesia. During the next three weeks a transient, soft sys-

tolic murmur was audible. The dog was in good health. Subsequently the murmur disappeared and the animal was reoperated on six weeks after the first procedure. Two intravenous inoculations with *Streptococcus viridans* were administered, and this organism was recovered in pure culture at intervals until death. One month after the second operation auscultation of the heart revealed a moderately loud systolic murmur, no second sound and a short early diastolic rumble. The dog gradually became lethargic, would not stand, refused food and water, and died on the forty-second postoperative day. The heart was not removed until several hours later.

Fig. 2.—Microscopic appearance of the base of the mitral valve shown in figure 1. The section shows granulation tissue on the surface of the valve, myocardial necrosis, and a heavy infiltration of inflammatory cells into the subendocardium.

Gross Description: The heart was of normal consistency and showed a healed incision on the anterior surface of the left ventricle. The various chambers of the heart were free from thrombi, and the valves, with the exception of the mitral, were normal.

When examined from above, the mitral valve showed remarkably thickened segments and on palpation would not admit the tip of the little finger (fig. 4). The mitral orifice presented an irregularly oval opening which was slightly over-

hung by a thickened, contracted ridge of auricular endocardium about 3 mm. above the margin of the valvular segments.

On cut section the valve was thickened, especially along the free margin, and tough and fibrous in consistency.

Microscopic Description: The section included a portion of the auricular and ventricular walls and the entire mitral leaflet. The area of involvement was

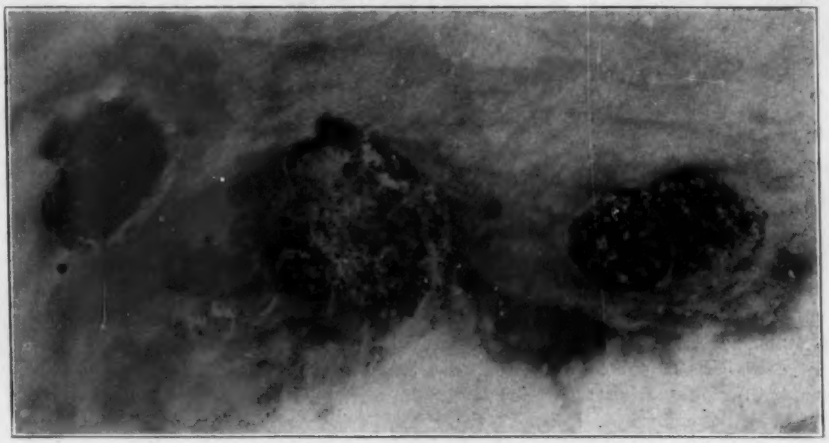

Fig. 3.—Clumps of bacteria embedded in a thrombus.

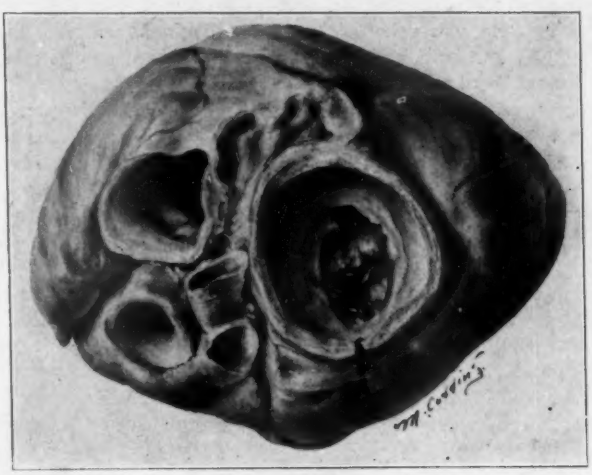

Fig. 4.—Experimental mitral stenosis in dog B-19. The segments of the valve are thickened and the orifice does not admit the tip of the little finger. The animal died of cardiac failure six weeks after the onset of acute endocarditis.

approximately the same as in the heart previously described. A notable difference in the two sections, however, was at once apparent in the amount of organization that had occurred. At the base of the valve was an extensive proliferation

of fibrous tissue with the formation of fibrocartilage at the junction of the inferior surface and ventricular endocardium. New blood vessels were prominent about the outer limits of this dense scar tissue, and fibroblastic proliferation was evident. Enclosed within the scar tissue at the base of the valve was a necrotic mass of formless material in which no cellular elements were recognizable. The subendocardial granulation tissue on both auricular and ventricular surfaces was carried out onto the tremendously thickened valvular leaflet, and in most fields small, thin walled blood vessels were seen embedded in the fibrous tissue. On the distal end of the valve there was still some formless, necrotic material in which hemosiderin was found.

Dog B-25.—Electrocoagulation of the mitral valve was performed under ether anesthesia. A soft systolic murmur was audible after the operation. One month later the dog was given two intravenous inoculations with cultures of *Streptococcus viridans*. Subsequently, the murmur was slightly accentuated. The animal was reoperated on and reinoculated twice with 100 cc. of a similar culture. One week later this organism was recovered from the blood stream.

Three months after the second operation, auscultation of the heart revealed reduplication of the second sound but no definite diastolic murmur. The dog was in good health. The blood culture was negative. The animal was killed four months later, and the heart was removed immediately.

Gross Description: With the exception of the mitral valve, the general appearance of the heart was identical with that of the preceding one.

When examined from above, the mitral orifice was reduced in caliber and did not quite admit the tip of the little finger. At the anterior junction of the aortic and lateral segments a somewhat polypoid, puckered, cartilaginous nodule was apparent. The aortic segment and midportion of the lateral segment were markedly sclerosed and measured 3.5 mm. in thickness. On the scarred margin of the lateral segment was a hard, smooth, cartilaginous nodule 3 mm. in diameter. This appeared to be a healed vegetative lesion because of its intimate relationship to the puckered, scarred, valvular margin.

The aortic segment was much thickened, tough and fibrotic (fig. 5). On the inferior surface, at the junction with the ventricular endocardium, was a small, cartilaginous nodule similar to that on the superior surface of the lateral segment.

In cross-section both lateral and aortic segments presented a fusiform contour with the greatest thickening in the proximal third just distal to a slight constriction at the base (fig. 6).

Microscopic Description: The tissue was taken from the specimen shown in cross-section in figure 6. Portions of the auricle and ventricle and the entire aortic segment were included. There was no residual exudate on the valve. The leaflet was markedly fibrotic and presented a fusiform thickening of the inner half largely due to the replacement and ingrowth of fibrocartilage. There was also a large area of fibrocartilage near the base. The cartilaginous character of the tissue was manifested by the presence of typical, clear cells embedded in a deeply basic staining matrix (fig. 7). At the borders of these cartilaginous areas there was a gradual transition into dense acellular connective tissue. Vascularization was apparent on the superior surface of the leaflet, where several precapillary sized blood vessels were seen.

Human Lesions.—Case A-29-3.—A white woman, aged 34, was brought to the hospital because of bronchopneumonia and diabetes mellitus. The history disclosed the fact that she had been treated for cardiac valvular disease of rheu-

matic origin eleven years previously. Physical examination of the heart was unsatisfactory because the sounds were obscured by harsh breathing and a loud, pleural friction rub. The patient was moribund on admission and died a few hours later. Necropsy was performed.

Fig. 5.—Experimental mitral stenosis in dog B-25. Both segments of the valve are markedly thickened and sclerosed. The orifice would not admit the tip of the little finger.

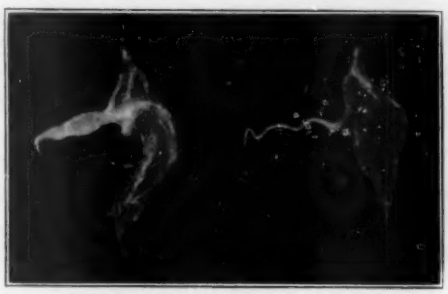

Fig. 6.—Vertical section through the aortic segment of the stenotic mitral valve shown in figure 5, and through a normal valve for comparison. The valve at the left is densely scarred and thickened; at its base is a firm cicatrix composed largely of fibrocartilage.

Gross Description of Heart: The heart was moderately hypertrophied and dilated and weighed 395 Gm. The myocardium of the left ventricle measured 15 mm. in thickness; that of the left auricle, 4 mm. The right side of the heart showed no abnormality.

There was some thickening and fibrosis of all the segments of the aortic valve. The endocardium of the left auricle showed several roughened and puckered areas.

The mitral valve presented the characteristic appearance of moderate stenosis with superimposed vegetative endocarditis. When examined from above, the orifice admitted only one finger. There were several grayish-red, warty vegeta-

Fig. 7.—Microscopic appearance of the base of the mitral valve shown in figures 5 and 6. The section shows the formation and ingrowth of fibrocartilage.

tions, from 1 to 3 mm. in diameter, along the margin of the lateral segment. They were slightly friable but were not easily broken away from the endocardium. A noteworthy feature was the presence of numerous capillaries forming a veil-like network over the valvular endocardium (fig. 8). (These vessels have been rendered prominent by injection of the coronary circulation with a suspension of bismuth subchloride in acacia.) On cut section the valve was thickened throughout its length, especially in the distal half, where it measured 3 mm. (fig. 9).

Fig. 8.—Mitral stenosis of rheumatic origin in case A-29-3, showing vascularization of the valve and superimposed vegetative endocarditis. The vessels have been rendered prominent by injection of the coronary circulation with a suspension of bismuth subchloride. (Compare the gross appearance of this valve with that shown in figure 5.)

Fig. 9.—Vertical section through the valve shown in figure 8. There is a marked increase in the thickness of the segment. (Compare with figure 6.)

Microscopic Description: The histologic examination included a cross sectional study of the entire mitral valve and portions of the adjacent auricular and ventricular walls. In the ventricular myocardium at the base of the valve there was a wide area of scar tissue with fibrous bands running out for great distances between individual muscle fibers and bundles of cardiac musculature. A scattering of lymphoid and plasma cells persisted in this fibrous tissue. Near the base of the valve were numerous cicatrices about small blood vessels. In

Fig. 10.—Severe mitral stenosis with marked thickening and scarring of the entire valve in case A-29-14. (Compare with the experimental lesion shown in figure 4.)

some instances these scarred areas were quite heavily infiltrated with lymphoid cells and endothelial phagocytes.

The mitral valve itself was long and uniformly thickened. The endocardium was intact except at the tip, where a small organizing thrombus was attached. Capillary and precapillary sized blood vessels were prominent throughout the entire length of the valvular leaflet. The valve itself was devoid of cellular infiltration; it was dense and fibrous. The subendocardium on the auricular side was more prominently thickened than was that on the ventricular aspect.

CASE A-29-14.—A white man, aged 48, entered the hospital because of edema of the ankles, dyspnea and precordial pain. The history revealed the fact that he had had rheumatic fever at the age of 18 and again at the age of 28. Physical examination showed cardiac enlargement, a presystolic thrill, a rough presystolic murmur, and a loud snapping first sound. There were signs of fluid at both bases. The patient died of cardiac failure.

Gross Description: The heart was markedly hypertrophied in all chambers and weighed 495 Gm. The myocardium of the left ventricle measured 18 mm. in thickness; that of the right ventricle, 6 mm.; the left auricle, 6 mm.; and the right auricle, 4 mm. In addition to the hypertrophy, there was marked dilatation of all chambers, especially of the left auricle and to a less degree of the right auricle.

The pulmonic valve was normal. The aortic valve showed thickening of its segments with fusion of the anterior and right lateral cusps. At this point there was also some calcification. The tricuspid valve was moderately thickened and stenosed. The orifice admitted only the tips of two fingers.

The mitral valve was of the "fish mouth" variety and would not admit the tip of the little finger (fig. 10). The orifice was crescentic in appearance and measured 7 mm. by 1 mm. in its greatest dimensions. There was marked wrinkling and puckering of the entire valve and to a less extent of the endocardium of the left auricle. A small, friable thrombus was attached to the auricular wall on the interauricular septum. One circumscribed cartilaginous elevation was present on the aortic segment. No vegetations were apparent.

Microscopic Description: The histologic appearance of the mitral valve was similar to that described in case A-29-3. Thickening of the valvular segment was more pronounced, and small blood vessels were more numerous. There were also a few small foci of round cells embedded in the dense fibrous substance of the valve. There was no remaining cellular response in the myocardium of the adjacent auricular or ventricular walls.

SUMMARY AND CONCLUSIONS

The vegetations of acute endocarditis produced experimentally in dogs by electrosurgical traumatization of the mitral valve and subsequent intravenous inoculation with cultures of *Streptococcus viridans* are similar to the vegetations of subacute bacterial endocarditis in man. In some cases it is possible to demonstrate microscopically clumps of bacteria included within the thrombi. Some of the larger areas of necrosis which occur in the experimental lesions may be attributed to the coagulation of tissue produced by the operative procedure. Heavy infiltration of inflammatory cells occurs in both types. In the more chronic experimental lesions, repair occurs by avascular cicatrization; in the human lesions, vascular organization is usually more prominent. The human hearts show more shortening of the cordae tendineae and a more diffuse, complete involvement of all the segments of the valve.

In the favorable canine lesions which go on to complete healing, fibrocartilage is laid down. A thickened, fibrous valve is produced which is somewhat comparable to mitral stenosis of rheumatic origin in man.

HEREDITARY DEFORMING CHONDRODYSPLASIA*

REPORT OF A CASE

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Considerable interest has recently been aroused concerning a disease entity of the skeleton which has been referred to most commonly as multiple cartilaginous exostoses. Certainly the manifestation of interest in the disease in America can be said to be recent, for the first case reported in this country was by Gibney [1] in 1875. Not unlike most disease entities of the skeleton, this disease has been given a name by almost every author who has written about it. Like practically all of the hereditary disease entities of the skeleton, its etiology remains a mystery.

It is not within my province in this paper to discuss in detail the disease itself, for this has been adequately done in a number of relatively recent papers, particularly in that of Albert Ehrenfried.[2]

The studies here are devoted to three aspects of the disease: (1) a brief study of the disease as represented by the case reported in this paper, including the hereditary and familial features; (2) a consideration of the changes that occurred in one of the tumors and that suggested malignancy; (3) a comparative study of this disease with chondrodystrophia fetalis.

Hereditary deforming chondrodysplasia is characterized by a number of definitely recognized features. It is hereditary and familial, having been traced through five generations in several instances. Both males and females may transmit the disease, and while it may be transmitted by an unaffected female, there is no evidence that it can be transmitted by an unaffected male. It has been recorded that two mothers had affected children by different husbands, and that one father had affected children in two marriages. There is a tendency to conform to the mendelian law of inheritance, and males predominate in the proportion of 3:1.

In attempting to find an etiologic factor, Virchow and others have considered the condition secondary to rickets. However, aside from the fact that the microscopic cross-section of the diaphysis and epi-

* Submitted for publication, Feb. 3, 1930.

* From the Department of Surgery of the University Hospital.

1. Gibney, V. P.: Multiple Exostoses, Med. Rec. **10**:300, 1875.

2. Ehrenfried, A.: Hereditary Deforming Chondrodysplasia—Multiple Cartilaginous Exostoses: A Review of the American Literature and Report of Twelve Cases, J. A. M. A. **68**:502 (Feb. 17) 1917.

physis presents a considerably different picture in the two disease entities, there are certain clinical facts which also militate against this possibility. Among the numerous instances of recognized rickets, this chondrodysplasia is not seen to occur, and so far as my observations have been concerned, certain characteristics which show up in rickety bone ends, such as the parallel transverse lines of increased density, are lacking in this disease. Furthermore, the pathologic change in rickets consists essentially in the production of osteoid tissue with a deficiency in calcification, whereas here one is dealing with a distorted, unregulated line of ossification and sometimes indeed with a premature ossification of the intermediary cartilage. The latter probably accounts for some of the shortening of the extremities and has suggested to some a resemblance to chondrodystrophia fetalis. Again, the treatment for rickets is a well recognized and standardized therapeusis affecting a cure, whereas similar treatment has no curative or abating effect on the disease in question. Histologic studies have been made which bear adequate witness against an identity of the two diseases.[3] Other etiologic factors that have been mentioned are: the thyroid gland, a trophic disturbance due to a degenerative disease of the nervous system and syphilis and tuberculosis.

Although the primary factor is not established, it would seem to me that at least one fact is tenable and clear, that cartilage rests are left in the wake of a chaotic advancing epiphysis, and these rests undoubtedly form the nucleus of the anomalous benign tumors. Ehrenfried's microscopic studies of such epiphyses and bones bear this out, and, of course, whether one encounters a sessile tumor on the shaft or a central tumor expanding the cortex depends on the location of the cartilage rest.

Sir Arthur Keith,[4] carrying the analysis further and offering a somewhat different explanation, maintained that a retardation or absence of the pruning and modeling process in the diaphysis is the responsible factor, and he proposed the name "diaphysial aclasis" to designate the disease.

Briefly, the disease may manifest itself in any of the bones formed from cartilage but not in intramembranous bones. Hence the cranium is seldom affected. An occasional exostosis and spur have been reported as occurring on the cranial vault and from the basilar process at the spheno-occipital junction, but by far the more common observation in all the case reports studied is a normal cranium.

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3. Pels-Leusden: Klinische, pathologisch-anatomische und ra[illegible]ologische Studien über Exostosis cartilaginea multiplex, Deutsche Ztschr. f. C[illegible]r. **86**:434, 1907.

4. Keith, A.: Studies on the Anatomical Changes Which Accompany Certain Growth Disorders of the Human Body, J. Anat. **54**:101, 1919.

Interesting complications have been reported owing to the location of the growth and mechanical pressure. Outstanding examples are those which cause neurologic symptoms due to pressure on the spinal cord and intrapelvic growths causing dystocia in the birth canal.

Dr. Boggs,[5] in 1913, reported an interesting case in which the patient presented an optic and acoustic nerve degeneration, but he concluded that these were not attributable to the skeletal disease. Dr. Bloodgood in a discussion mentioned two of his collected cases in which the lesions showed cyst formation. He stated further that multiple enchondromas and exostoses are the only two congenital lesions of the skeleton producing cyst formation. Other diseases mentioned which produce cyst formation are: osteitis fibrosa (von Recklinghausen's disease), osteitis deformans (Paget's disease), osteomalacia and mercurial poisoning. He also stated that no examples of malignant degeneration had been observed in multiple congenital osteochondromas.

The tumors have been reported present at birth and appearing as late in life as the age of 50, although it is more common to find their growth coincident with that of the normal bone. Recession in growth after puberty has also been reported.

Among the many varied and interesting characteristics of the tumors themselves as they occur in the various enchondral bones, which have been discussed in detail by Ehrenfried, is the peculiar distorted development of the ulna and fibula, particularly as compared with that of the radius and tibia, respectively. The lower end of the ulna and both ends of the fibula may be lacking considerably in necessary length, ending with a distorted, perhaps squared or rounded off end, presenting a foam-like roentgenographic appearance. The disproportionate development of the two bones in the forearm and in the leg gives rise to a distorted and crippled appearance of the extremities, particularly of the hands, such as manu vara, dislocation of the head of the radius and a weak wrist joint. An adequate explanation of these almost constant disproportions has not been made. A comparison of the times of ossification and union of the epiphyses does not offer enough discrepancy to arouse interest. (The heads of the ulna and radius ossify at the tenth and fifth years and unite at about puberty. The distal ends ossify at the fourth and second years and unite at the twentieth year. The heads of the tibia and fibula ossify shortly after birth and about the fourth year, respectively, and unite at the twentieth and twenty-fifth years. The distal ends ossify at the second year and unite at the eighteenth and twentieth years.)

A possible explanation for this interesting deformity which occurs where two bones are in juxtaposition, as in the forearm and leg, may

5. Boggs: Bull. Johns Hopkins Hosp. **24**:210, 1913.

be found in the diversion of the normal epiphyseal growth. In the instances in which one of the two bones has stopped short of its normal growth and one of its ends presents a stublike deformity as if part of the bone had been melted away, one sees proximal to this an enchondroma abutting the shaft of the adjacent bone. In some cases the latter, apparently reacting to the stimulus of the former, throws out a bulwark of bone to meet it. The resulting picture is that of a pseudo-joint, and thus it is not illogical to assume that in this way the normal linear epiphyseal growth is distorted laterally and the stimulus for linear growth stunted if not completely lost. How this factor could play such a role in both the forearm and the leg is shown in figure 1, taken from McFarland's report of a case.[6] It can also be seen in the case presented here (figs. 4 and 7).

Fig. 1.—Roentgenograms of the arms and legs of McFarland's patient (Surg. Gynec. Obst. **48**:268, 1929). Note the effect of pseudo-joint formation on the growth of the ulna and fibula.

The tumor itself varies in its content of bone, but is practically always less dense than the adjacent normal bone. If it is centrally located, it expands the cortex. Roentgenologically, it presents the "lace curtain effect" or "foamlike" structure, resembling in some ways the giant cell tumor of bone. Delicate bone septums encase the less dense cartilaginous tissue. Although these tumors may grow to an enormous size, in a roentgenogram they present only in rare instances an appearance that is the least suggestive of malignancy such as is found in sarcoma of the bone.

REPORT OF CASE

History.—Daniel T., a white man, aged 48, a native of Iowa, first entered the University Hospital on June 30, 1927, with a complaint of a slightly painful tumor of the right hip. The patient's father was of Irish descent and died of pneu-

6. McFarland, J.: Hereditary Deforming Chondrodysplasia, Surg. Gynec. Obst. **48**:268, 1929.

monia at the age of 67. He was 5 feet, 2 inches (153 cm.) tall and presented what the family referred to as the "Toher mark" (short extremities and an inability to extend the forearms fully). It is interesting that the hereditary nature of this disease has been so impressed on the family for at least three generations that it has been referred to as the "Toher mark," the family name being Toher. The patient's mother was also of Irish descent and died of pneumonia at the age of 87. Neither she nor her ancestry presented the Toher mark or other skeletal deformity. She had a fleshy tumor removed from the calf of the leg at middle age. The father had two brothers, both of whom presented the Toher mark. One had an elevation of one of his shoulders, which was attributed to a bony tumor. The other's arms were limited in extension to about

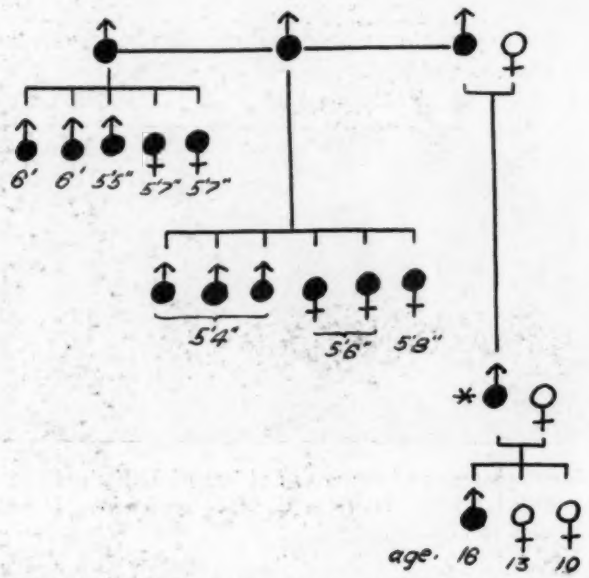

Fig. 2.—Family tree of Daniel T., showing hereditary and familial tendency of deforming chondrodysplasia. Affected persons are represented by the completely shaded circles, the unaffected persons by the unshaded circles. The asterisk denotes my patient.

45 degrees. One brother was the father of five children, three of whom were short in stature and two were 6 feet (183 cm.) tall. One of the former was knock-kneed to such an extent that his legs were straightened by operation. All of the children, however, presented the Toher mark. The second brother had six children, all of whom showed this mark. The patient had three children, one boy and two girls. The boy was 16 years of age and was 5 feet, 9 inches (175 cm.) tall, and although he did not present the Toher mark, a bony tumor had developed under the right knee since the onset of puberty. The girls were 13 and 10 years of age, and presented no visible deformities. A plan of the family tree is shown in figure 2.

The patient said that he had not had syphilis or gonorrhea. He did not use alcohol, but used tobacco freely. He had had the ordinary diseases of childhood and diphtheria, and he had had rheumatic fever and sciatica at the age of 10.

Three ribs were broken in 1910. He had had no other accidents and no operations. The cardiovascular, cardiorespiratory (except for frequent colds), the genito-urinary and the gastro-intestinal systems were normal. The nervous system was normal, except for the pathologic changes in the present illness.

The patient complained of multiple tumors over his body, which first attracted his attention at about the age of 14 and grew progressively as he grew. (He was born with the "Toher mark" but, to his knowledge, not with the enchondromas). The tumors were not painful or tender until August, 1926, when the one at the right hip began to be tender and to enlarge rather rapidly. He began to

Fig. 3.—Daniel T. (April 29, 1929). Note the limit of extension and deformity of the left forearm, tumors of the right hip and thigh and the lack of achondroplasic features of the cranium.

feel "sciatic pain" down to the foot in the region of the sciatic nerve. The foot grew somewhat numb and tingled, especially on the plantar surface. The toes became slightly bluish, and though the feet had always perspired a great deal, this one became dry. There were no other complaints.

After the first two roentgen treatments, he said that all of these phenomena disappeared, and the feet again became alike.

Examination.—Physical examination showed the patient to be about 5 feet, 6 inches (167.5 cm.) tall, well developed and well nourished, an intelligent white

American man, appearing to be about 45 years of age. He came to the clinic on crutches, with an obvious flexion deformity of the right hip and markedly limited motion of the same. He did not appear to be in any pain, and the physiognomy appeared normal.

The skin was warm and of normal thickness and consistency. There was a normal amount of moisture. No lesions were seen, and the growth of hair was normal for the male. The head was of normal shape and contour with a fair growth of slightly gray hair which was not unusual. The eyes were blue, and were not unusual. The ophthalmoscopic observations were negative.

The ears and nose presented no objective or subjective abnormalities. The teeth were in poor condition, and the tongue was rather deeply furrowed. The

Fig. 4.—Roentgenogram of the forearms of Daniel T. (July 2, 1927).* Note particularly the unfinished development of the distal end of the ulna and the enchondroma proximal to this. The attempt at pseudo-joint formation here has probably diverted the stimulus for epiphyseal growth.

tonsils were mildly hypertrophied, and the pharynx was mildly injected. There were a few small, soft and movable glands in the posterior triangles of the neck. The thyroid gland was not palpable, and there was no suggestion of stiffness of the neck.

The chest was symmetrical, well formed and of good and equal expansion. Litten's sign was present. The lungs were normal to percussion and auscultation. The point of maximum impulse of the heart was felt at the fifth intercostal space just inside the nipple line. It was not enlarged to percussion, and auscultation revealed no irregularities or murmurs. The pulse rate was 16 to the quarter, regular and of good volume and fair tension. The arterial walls were soft and elastic. The blood pressure was 110 systolic and 70 diastolic.

The abdomen was normal in appearance, being slightly rotund. There was no tenderness, fluid or masses to be felt. The solid organs were not felt.

The knee reflexes, ankle jerks and biceps, triceps and abdominal reflexes were equal and active on the two sides.

Both forearms and upper arms appeared shorter than normal. Both arms measured 28 cm. from the point of the shoulder to the external condyle of the humerus, and the forearms measured 21 cm. from the olecranon process to the region of the styloid process of the ulna. The left forearm was limited somewhat

Fig. 5.—Roentgenogram of the left humerus of Daniel T. (Oct. 2, 1927), showing exostosis in about the midshaft region.

in extension, as can be seen in figure 3, and the examiner at first thought that there was a congenital absence of the ulna. The upper third of the right humerus presented a nodular tumor fixed to bone and having the feel of an exostosis. The left humerus presented a similar tumor. The left lower extremity presented a similar tumor on the inner aspect of the lower third of the thigh. The right lower extremity presented a large tumor in this same relative location and a large tumor of the right hip. The latter tumor was a large symmetrical swelling which had eradicated the gluteal fold. The skin surface over it was slightly reddened and freely movable. The tumor was fairly well outlined and rounded. It was fixed securely to bone and was of bony consistency and smooth, but there was a sense of fine irregularity. It was tender centrally to gentle pressure and

was the seat of the patient's pain. None of the other tumors was tender to even firm pressure. There was a fair degree of extension of the thigh, but flexion was quite limited. At the time of writing, the circumference of the right hip was 72.5 cm. compared with 58.5 cm. of the left. The circumference of the right thigh in the region of the lower tumor was 55 cm., compared with 50 cm. on the left.

The laboratory examination was made on June 30, 1927. The blood count was: hemoglobin, 75 per cent; red cells, 4,800,000; white cells, 6,550; differential count: polymorphonuclear neutrophils, 76 per cent; polymorphonuclear eosinophils, 3 per cent; small lymphocytes, 15 per cent, and endocytes, 6 per cent.

Fig. 6.—Roentgenogram of the right femur of Daniel T. (April 4, 1929), showing large enchondroma in which chondromatous changes are beginning to take place comparable to those in the hip. Note also the small exostoses.

Urinalysis showed: color, amber; specific gravity, 1.030; albumin, 0; sugar, 0; acetone, 0; pus, blood and casts, 0. The Bence-Jones test for protein was negative.

On April 29, 1929, the blood calcium was 14 mg. per hundred cubic centimeters.

Roentgenograms of the entire skeleton were taken, some of which are reproduced here. On June 30, 1927, Dr. T. F. Baxter reported a large osteoid type of bone tumor involving the region of the right hip, at that time a benign tumor with none of the characteristics of sarcoma or carcinoma. There were also benign congenital osteoid tumors involving the lower shaft of the right femur,

upper portion of the right tibia, upper portion of the left humerus, distal portion of the left clavicle, upper portion of the right humerus, chondral portions of the anterior regions of the ribs (more marked on the left side), both the right and the left radius and ulna (with deformity and widening of the shafts and marked deformity of both wrist joint areas and to a less extent of both elbow areas), lower portion of the shaft of the left femur, upper portion of the shaft, head and neck of the left and the right fibula and also of the right and the left tibia, with evidence of a large pressure defect in the lower portion of the shaft and supracondyloid area of the left fibula.

There was evidence of slight osteo-arthritis of the cervical spine and hypertrophic osteo-arthritis and some scoliosis of the dorsal and the lumbar spine.

Fig. 7.—Roentgenogram (July 2, 1927) of the legs of Daniel T., showing enchondromas. Note particularly the pseudo-joint formation at the distal ends of the left tibia and fibula and the thinning out of the fibula beyond this joint.

Course.—The patient returned to the hospital on September 27, at which time a check-up roentgenogram of the right hip was taken. The impression at this time was that the original osteochondroma had undergone malignant degeneration and exhibited the characteristics of osteochondrosarcoma. It was stated that it showed little or no evidence of extension since July 2, 1927. There was evidence of a pathologic fracture through the neck of the right femur and of some reparative process in the tumor itself. From that time until the time of writing, the patient had returned every three months for roentgen therapy for what was considered an osteogenic sarcoma. The evidence of pathologic fracture had disappeared on April 25, 1928. Similar changes were occurring in the tumor of the lower third of the right femur and by the same token had been regarded as malignant changes. The tumor of the hip had been growing steadily and rather rapidly and had been increasing markedly in its calcific content, which was being

laid down in multiple spots and in ringlike foci. Destruction of bone was not discernible in the most recent roentgenograms, those of the hip and the thigh being reproduced here.

At the time of writing the patient, so far as his systemic condition was concerned, was enjoying excellent health. His appetite was good, and he said that he had recently gained some weight. The tumors of the hip and thigh in question, however, had obviously grown larger, and the former was somewhat tender in places to moderately deep pressure. The history concerning pain in the hip was not altogether clear, although he felt certain that it was alleviated considerably by the first roentgen treatment. It had been better and worse at intervals since, and at the time of writing was so severe as to keep him awake a great part of the night.

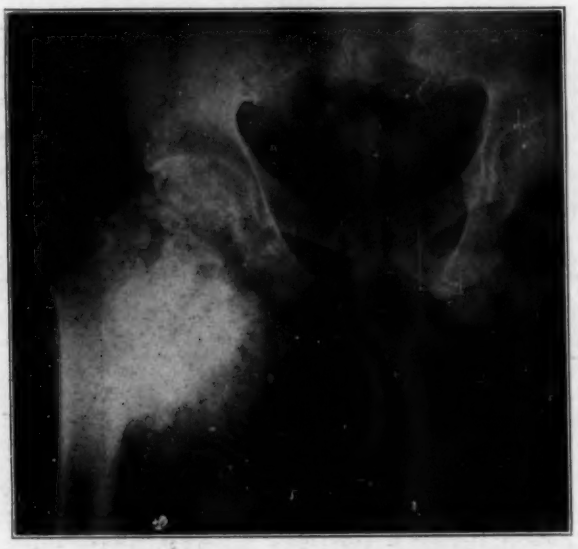

Fig. 8.—Roentgenogram (July 2, 1927) of the right hip region of Daniel T., showing an osteochondroma. Note in all these pictures of the hip the absence of bone destruction and the ringlike manner in which the calcium is laid down in places.

The hip was completely fixed, and the skin over it was flushed and tightly stretched. Sensation of the extremity as compared with that of the opposite side appeared to remain normal, and both feet were of equal temperature, moisture and color.

The patient therefore presented marked and interesting changes which probably had taken place in one of the enchondromas and which merit some consideration as to their status between benignity and possible malignant changes. Cases of "malignant degeneration" of enchondromas have been reported in the older literature. These cases comprised about 5 per cent of all the cases of hereditary deforming chondrodysplasia that Ehrenfried was able to collect. Twenty-four

cases were reported in 1905 by Lenormant and Lecène.[7] The majority of these tumors reported by the older authors, however, are called chondromas or enchondromas, and the issue seems to have rested on the authors' opinion of the pathologic status of chondroma. In reference to all the literature reviewed so far, there seems to be no evidence, except possibly in a single instance, that any of the malignant changes are other than chondromatous or osteochondromatous.[8] A few of the reports are accompanied by roentgenograms, and these bear out the foregoing statement. Dr. Ehrenfried has felt, since the publication of his exhaustive study of hereditary deforming chondrodysplasia in 1917,

Fig. 9.—Roentgenogram (Oct. 12, 1928) of the right hip of Daniel T. The apparent destruction of bone in the great trochanter here is due to a faulty roentgen exposure.

that instances of true malignant degeneration must be far more rare than he at first thought, and that there has probably been some confusion in making a differential diagnosis between hereditary deforming chondrodysplasia and chondromatosis. Bloodgood, in discussing Bogg's case, stated that there were no examples of malignant degeneration in multiple hereditary enchondromas and exostoses.

7. Lenormant and Lecène: L'association des exostoses et due chondrome des os, Rev. d'orthop. **7**:203, 1906. Lenormant: Exostoses osteogéniques et les chondromes des os, Rev. d'orthop. **6**:193, 1905.

8. Dr. Ehrenfried assisted me in obtaining these references.

The significant features of the tumor in the case reported here, which apparently arose from the proximal end of the right femur, are: the relatively rapid growth and expansion, the extensive calcification or ossification, the absolute lack of visible evidence of bone destruction in the x-ray picture and over at least a three year period a systemic condition incompatible with malignancy. The x-ray picture shows that the calcium has been laid down in multiple foci and in ringlike structures, the latter pointing more strongly to a simple calcification in

Fig. 10.—Roentgenogram (April 26, 1929) of the right hip of Daniel T. Note the extension of the tumor mesially and beyond the great trochanter.

the walls of degenerating cysts than to actual foci of ossification. I feel that such an observation in the x-ray picture characterizes this type of tumor. So far as I can ascertain, it is not found in osteogenic sarcoma, and such a design plus the absence of bone destruction can be taken as adequate evidence against that form of tumor.

In the following brief presentation of selected cases, a comparative study is made of the tumor in my patient and similar tumors reported in the literature. The latter have fallen into two classes: (1) those which illustrate a single and no doubt acquired chondroma in which

there are no hereditary features[9] and (2) those which are reported as being associated with multiple exostoses and which, though the hereditary factor of multiple exostoses and enchondromas is not stressed, are assumed to belong in the class of hereditary exostoses and enchondromas or hereditary deforming chondrodysplasia.[10]

Paul Rostock[11] reported a case of chondroma of the hip which, although not of the hereditary type, will serve for comparison here. The two pictures have many points in common, and I believe it reasonable to suspect that the tumors are of essentially the same pathologic process. After an extensive study of his case, Rostock concluded that the tumor was a benign chondroma and in general that such tumors do not become malignant and are not initiated by trauma. These views are in accord with those of Lexer.

Lexer[12] reported a case of chondroma, the x-ray picture of which indicated the same fundamental pathologic changes as in the case in point. A colored drawing of the specimen in cross-section is also shown in his report.

Kienböck,[13] in a discussion of chondromas and sarcomas of bone, also showed x-ray pictures of ossifying chondromas which are excellent for comparison with the present case. He also regarded such tumors as benign.

Percy[14] reported a case of multiple chondro-osteoma in which a tumor was situated in the midregion of the right humerus. It increased in size rather rapidly, beginning its change at about puberty and enlarging from that of an orange to that of a coconut in three years. The x-ray picture of this tumor is shown in his report, but it is a picture slightly different from the one discussed here. In the tumor in

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9. Rostock, P.: Die Unfallbegutachtung der Gelenkchondromatose, Arch. f. Orthop. **26**:593, 1928. Lexer, E.: Gelenkchondrome, Deutsche Ztschr. f. Chir. **88**:311, 1907. Kienböck, R.: Ueber Gelenkkopselschondrome und Sarkome, Fortschr. a. d. Geb. d. Röntgenstrahlen **24**:468, 1917.

10. Percy, N. M.: Multiple Chondro-Osteoma, Surg. Gynec. Obst. **20**:619, 1915. Gangolphe, M., and Gabourd, T.: Enorme enchondrome costal chèz un sujét exostosique, Rev. d'orthop. **8**:201, 1907. Weber, O.: Zur Geschichte des Enchondromes namentlich in Bezug auf dessen hereditäres Vorkommen und secundäre Verbreitung in inneren Organen durch Embolie, Arch. f. path. Anat. u. Physiol. **35**:501, 1866. Haberer, V.: Ein Fall von multiplen Enchondromen und Exostosen, Arch. f. klin. Chir. **89**:782, 1909. Stark, H.: Ueber Multiple Cartilaginäre Exostosen und deren klinische Bedeutung, Beitr. z. klin. Chir. **34**: 508, 1902. Läwen, A.: Ueber die Beziehungen der Enchondrome zu den multiplen cartilaginosen Exostosen, Deutsche Ztschr. f. Chir. **75**:14, 1904.

11. Rostock (footnote 9, first reference).

12. Lexer (footnote 9, second reference).

13. Kienböck (footnote 9, third reference).

14. Percy (footnote 10, first reference).

Percy's case the growth expanded in spicules and laminae rather than in the soap bubble and ringlike formations of the one in the patient whose case I have reported. Indeed one sees in his picture a sunburst effect which itself is not unlike that in osteogenic sarcoma, but there is no evidence of bone destruction. The report is of special value, as the tumor was removed and the pathologic changes were reported.

The pathologic report was given as follows:

Gross.—The tumor is hard and cauliflower-like in appearance. It measures 13.5 cm. by 12.5 cm. in diameter. The surface of the whole tumor is covered with a layer of glistening cartilage 3-6 mm. in thickness. Beneath the cartilage is a mixture of bony and cartilaginous substance about 1 cm. thick. The remainder of the tumor consists of a framework of hard, bony material with many spaces resembling the medullary cavity of bone.

Microscopic.—The outer layer is all cartilage but just internal to it are deposits of calcium in the matrix of the cartilage. Deeper in the tumor the calcium deposits take on more of the appearance of bone in the shape of lamellae interspaced with dense cellular tissue resembling blood elements.

Pathological Diagnosis.—Osteoid chondroma.

Gangolphe and Gabourd [15] demonstrated a very large chondroma of the ribs which they incompletely resected, and which in its continued growth into the chest was fatal. The patient presented other exostoses. It may be observed that these rapidly growing chondromas are located practically always in or about joints, but that the exostoses are not infrequently at various distances from the joints. These authors quoted and endorsed Virchow in his belief that difference in vascularity has much to do with these two types of growth. They recognized the innocent benignity of the exostoses and advised no surgical attack unless there was unwonted encroachment on vital structures. On the other hand, they regarded the chondroma as malignant and advised its early and complete removal.

Weber [16] presented a case of multiple exostoses in which a very large, rapidly growing chondroma of the hip joint metastasized to the iliac veins and vessels of the lungs.

Haberer [17] demonstrated the case of a middle-aged man with multiple exostoses and enchondromas who showed large, rapidly growing chondromas of the left hip, distal end of the right femur, proximal end of the right tibia and the right calcaneus. X-ray pictures of this case are reproduced in his article and are comparable with mine.

Stark [18] presented a case of multiple exostoses, in one of which (on the right humerus) a malignant degeneration occurred. He quoted Chiari as believing that the condition originated from the marrow and

15. Gangolphe and Gabourd (footnote 10, second reference).
16. Weber (footnote 10, third reference).
17. Haberer (footnote 10, fourth reference).
18. Stark (footnote 10, fifth reference).

that the exostosis was probably responsible. Stark is of the opinion that such exostoses, which have practically the same structure and composition as normal bone, are only the coincidental location of a malignant condition, and that this is no more unusual than a sarcoma in normal bone. The author stated that this is the only case of a malignant change in an exostotic tumor that has been reported.

Läwen [19] presented a case of multiple cartilaginous exostoses. One of the tumors, involving the right scapula, part of the humerus and part of the clavicle, grew to be almost as large as the patient's chest. In his study of the case as to differentiation between malignant degeneration and chondroma, the former was ruled out, since the tumor had existed for about four years without apparent metastasis and since the patient was otherwise well.

Lenormant and Lecène studied rather closely the association of multiple exostoses and chondroma in the same patient and presented a number of case reports. They concluded that chondromas or osteochondromas may develop by superimposition on a previously existing exostosis or enchondroma, or that they may develop in a subject having multiple exostoses and enchondromas but independent of those lesions.

It will be observed that while part of the time I have been discussing the nonhereditary form of chondroma and part of the time a type of chondroma that has developed in a patient presenting multiple exostoses and enchondromas, there is adequate reason to believe that the two tumors are pathologically identical; that is, they are chondromas or osteochondromas. The terms chondroma and osteochondroma are used synonymously here since the degree of ossification does not alter the fundamental nature of the tumor. It must not be forgotten, also, that multiple exostoses and enchondromas are synonymous with hereditary deforming chondrodysplasia.

Thus it is at once obvious that a difference of opinion exists as to the pathologic status of chondroma. I think it can be conceded, however, that the concensus is against its being malignant in the accepted sense of the term.

COMMENT

It will probably be of value here to give a brief résumé of the pathology of chondroid tumors, much of which is taken from Ewing.

Limited outgrowths of preexisting cartilage occur on the ribs, in the larynx and about the joints, which exhibit the characters of simple hyperplastic processes and are called ecchondroses. True progressive neoplasms composed of cartilage appear in the same situations and also in tissues not normally containing cartilage, and these are called chondromas or enchondromas.

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19. Läwen (footnote 10, sixth reference).

It has long been recognized that chondromas have the property of rapid growth and may invade vessels and extend a long distance in them. They may grow into vessels and metastasize. Metastases are formed especially in the lungs. They have been known to invade the veins of the pelvis and extend to the heart. They undergo varying degrees of calcification and ossification. Ranvier has classified them in four groups according to their structure: (1) a single lobe of hyaline cartilage, (2) several lobes of hyaline cartilage separated by fibrocartilage, (3) fetal cartilage and (4) cartilage with stellate cells. Grossly, the tumors vary in consistency, some being soft and apparently more cellular than others. They undergo varying degrees of cystic degeneration and may ulcerate through the skin. It is likely that the vessel-invading and metastasizing propensities depend on the nature of the tumor as outlined. The metastatic lesions are most frequently found in the pulmonary vessels, and this fact bears witness that the metastatic lesion is a vascular embolic one, probably having broken from a part of the tumor invading a vein. As is frequently true of metastatic thyroid tumors, a cross-section of the metastasis cannot be distinguished from the normal forbear of the new growth, in this case normal cartilage.

A definitely malignant tumor (chondrosarcoma) is much more rare and differs from the foregoing in having definite infiltrative properties and being destructive of bone.

The chondroma, therefore, while having the property of invading vessels and truly metastasizing, is not malignant in the same sense and certainly not in the same degree as osteogenic sarcoma, and herein lies the tremendous difference in prognostic attribute. The chondroma strikingly lacks the debilitating and toxic influence of sarcoma of the bone. If a chondroma is inclined to metastasize, it undoubtedly does so late. If only a portion of the tumor is removed, the remainder will of course continue to grow; but if the gross tumor is completely excised, it will not recur. The indication therefore seems clear. A chondroma, whether it is of the nonhereditary type or whether it has developed on a skeleton presenting hereditary deforming chondrodysplasia, should be immediately totally excised so far as it is technically possible. It is doubtful whether roentgen therapy is of any benefit; it certainly is not curative.

In the case that I have reported it is hardly possible to tell whether the osteochondroma developed secondarily on a preexisting lesion or whether it devoloped independently, and in the light of the present study it would seem to me that such knowledge would at most be of only academic interest. I would add, however, that the association of osteochondroma with hereditary deforming chondrodysplasia is altogether too frequent to be regarded as merely coincidental. It would seem that the latter disease either by virtue of its own etiology or by

the disruption of the cartilage at the epiphysis has especially predisposed its victim to chondromatosis. These patients, therefore, should be followed up carefully from time to time so that any newly developing chondroma may be totally excised in its infancy.

CHONDRODYSPLASIA AND CHONDRODYSTROPHIA FETALIS

In groping for a classification of hereditary deforming chondrodysplasia and a fitting category in which to place it in the list of skeletal deformities, particularly among those of congenital and hereditary nature, authors have permitted themselves to see a close kinship to achondroplasia or chondrodystrophia fetalis. They have been impressed by the abnormal shortness of limb and often of stature of these patients, making their bodies, exclusive of the head, appear not altogether unlike the chondrodystrophic dwarf. This, together with the fact that the condition is primarily a disturbance in epiphyseal growth, has been, I think, the chief influencing factor.

Among those who have made statements regarding a comparison of the two diseases are Lewin [20] and Dwyer,[21] who maintain that there is a close kinship, and Carman and Fisher,[22] who are of the opposite opinion.

Dwyer based his comparison on the following facts: 1. Achondroplasia, according to Kaufman, may be present without dwarfing and with widely varying degrees of involvement. 2. Both conditions affect only those bones that develop from cartilage. 3. Aberrant cartilage inclusions may be found in bones in both conditions. 4. There is a similarity in the pathology of the epiphyseal line, in that both conditions cause a chaotic appearance of the epiphyseal cartilage at the line of ossification.

Although it is true that both diseases are manifestations of a disturbance in epiphyseal ossification and a distortion of the rows of cartilage cells—a distortion which may be either cause or effect—there are many fundamental differences between the two conditions to warrant a suspicion that the histologic resemblance is not conclusive; that is, although the seeds look alike, the mature plants bear considerable witness against their identity. Although it is true that there have been reported cases of incomplete chondrodystrophia, as in the two fetuses having involvement of the intracartilaginous bones of the head without interference with the growth of the long bones reported by

20. Lewin, P.: Multiple Cartilaginous Exostoses—Diaphyseal Aclasis, Surg. Gynec. Obst. **45**:48, 1927.

21. Dwyer, H. L.: Chondrodysplasia: Multiple Cartilaginous Exostoses, Am. J. Dis. Child. **19**:189 (March) 1920.

22. Carman and Fisher: Ann. Surg. **61**:142, 1915.

Kaufman, to all general intents and purposes true chondrodystrophia is a generalized disease. All of the epiphyses usually share the disorder equally, thus giving a generalized and symmetrical skeletal deformity. Again, while Schorr described a type of chondrodystrophia appearing at puberty, to which he gave the name chondrodystrophia adolescentium, the majority of chondrodystrophic persons either are born prematurely or are dead at term (Nathan [23]). Chondrodystrophia is therefore in the majority of instances a serious fetal disease and indeed an antenatal disease, whereas chondrodysplasia is usually postnatal in its development and manifestation, and fatality has scarcely deserved consideration except as attributed to distinctly secondary causes.

One of the most characteristic features of chondrodystrophia is the unmistakable appearance of the physiognomy. At birth the circumference of the head often equals the length of the body. As growth proceeds, the characteristic prognathous appearance and flattening of the nasal region result from a possible combination of several factors: premature synostosis and inhibition of the growth of the os tribasilare, shortening of the ethmoid and nasal bones with or without the foregoing and a reduction in the angle formed by the basilar process of the occipital bone and the body of the sphenoid, the latter condition being called by Virchow kyphosis of the saddle angle. I have seen no report of a case of chondrodysplasia in which the patient presented the characteristic physiognomy of chondrodystrophia, and the photograph of the patient presented here exhibits no such feature.

Added to this, one often finds thick lips, protruding, hypertrophied tongue and epicanthus, such features never to my knowledge having been described for chondrodysplasia.

Finally, the hereditary factor in chondrodystrophia is almost nil, as Nathan implied when he stated: "In one case a chondrodystrophic mother is said to have given birth to an infant similarly affected, but in all others we have nothing upon which to base a surmise as to the cause of this disease." For chondrodysplasia the facts are the contrary.

Nathan further stated that the female is somewhat predisposed in the former disease—his own cases were equally divided between the sexes—whereas in the latter condition males have distinctly predominated by three to one.

Therefore, although it is far from my intention to make a dogmatic statement, I feel that there is much to militate against the conception that the disease under discussion is an aberrant form of chondrodystrophia fetalis.

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23. Nathan, P. W.: Chondrodystrophia Foetalis, Am. J. M. Sc. **127**:690, 1904.

CONCLUSIONS

1. The so-called malignant degenerative lesions in skeletons presenting hereditary deforming chondrodysplasia are probably all chondromatous.

2. A chondroma developing in a skeleton showing hereditary deforming chondrodysplasia is essentially the same pathologic process as the nonhereditary chondroma and should be regarded in the same light.

3. Although such chondromas are essentially benign, they should, in view of their vessel invading and metastasizing propensities and rapid expansive growth, be totally excised as early as possible. Therefore, it is incumbent on the surgeon to make a check-up examination at intervals when he has diagnosed hereditary deforming chondrodysplasia.

4. Roentgenotherapy probably has no beneficial effect on this type of tumor.

5. The definite ringlike foci in which the calcium is deposited in the tumors, particularly in the absence of bone destruction, is adequate evidence on which to make a diagnosis of osteochondroma.

6. The marked deformity and foreshortening of either or both of two juxtaposed bones in hereditary deforming chondrodysplasia is probably due to pseudo-joint formation and distorted stimulus of bone growth.

7. There are so many factors militating against a possible kinship of chondrodystrophia fetalis and hereditary deforming chondrodysplasia that one would as yet seem unjustified in placing them in the same category.

SYNDACTYLISM

(COHERENCE OF THE FINGERS OR TOES)*

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The interest of surgeons in webbing of the fingers and toes is evidenced by the numerous contributions that have appeared in the literature during the last century and a quarter. Our own interest was stimulated by the care of a considerable number of these patients and by the fact that there still seemed to be much confusion about the subject. An attempt will be made in this paper to clarify the matter by tracing the deformity from its origin to its correction by the methods that have been most satisfactory in our hands.

DEFINITION

Congenital Syndactylism.—This type is an inheritable developmental defect characterized by complete or partial webbing of the fingers or toes. This malformation varies greatly in degree, from a slight distal extension of the normal web to complete fusion extending to the ends of the fingers.

Acquired Syndactylism.—Although usually a congenital malformation, syndactylism may be acquired and not infrequently follows severe burns or trauma of the hands or feet in which destruction of the tissues of the fingers or toes results in subsequent fusion of granulating surfaces.

The term "syndactylism" has been erroneously used in the literature to designate partial or complete lack of toes or fingers, but this type of defect is due to deep developmental disturbances while the webbing of the fingers or toes is merely indicative of an arrest in otherwise normal development. The cause of this arrest of development is as yet unkown.

CLASSIFICATION

Syndactylism may be classified according to the degree of fusion, as complete when it extends to the tips of the digits, and incomplete

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when the fusion is of a lesser degree. When the phalangeal bones are normal, the type is simple. When they are abnormal in size, shape, number and arrangement, the type is complicated.

The simplest type is that in which the web consists of the skin only, and this may be slack enough to allow the fingers to be separated to a considerable distance. More commonly the skin and underlying soft parts are involved, the fusion often extending to the ends of the fingers. Frequently there is only a shallow groove on each side to indicate the line of normal division. Sometimes the fingers may be even more closely fused, the nails being joined, and in extreme cases, the phalangeal bones also. The terminal phalangeal bones are those most frequently fused.

In certain types of syndactylism in which the web is thin, lax and short, there is little interference with function, except that the fingers cannot be widely separated. On the other hand, when the fusion is close, there is complete loss of individual digital function, and the fused fingers must necessarily be flexed and extended as one. This is frequently a serious handicap, and relief can be obtained only by surgical procedure.

In the acquired type, the web generally consists of dense scar tissue, and there is usually an associated contracture or distortion of the digits, but there is seldom, if ever, fusion of the bones. The acquired type may also be complete, but in the majority of instances the fusion is incomplete.

EMBRYOLOGY

The embryology of the extremities has been studied by Bardeen and Lewis [1] and by Lewis.[2] In the development of the embryo, the arm bud makes its apearance during the third week as a swelling in the lower cervical region. At this stage there is no differentiation of the mesenchyme, although a few thin walled blood vessels are present.

The condition of the hand at 4½ weeks is shown in figure 1. The border vein is present, but there is no evidence of differentiation in the hand plate.

During the fifth week, the hand plate shows several centers of increased condensation corresponding to the carpal bones. From the carpus, five masses of condensed tissue project; these are the finger masses. This stage is shown in figure 2.

By the sixth week, the metacarpals and phalanges have appeared as distinct masses of cartilage. No joint cavities are present, but the

1. Bardeen, C. R., and Lewis, W. H.: Development of the Back, Body Wall, and Limbs in Man, Am. J. Anat. **1**:1, 1901.

2. Lewis, W. H.: The Development of the Arm in Man, Am. J. Anat. **1**:145, 1901.

cartilages are separated by areas of condensed tissue. The intrinsic muscles of the hand are represented by late premuscle tissue and a few muscle fibers.

During the seventh week, the development of the metacarpals and phalanges proceeds rapidly, and the ligaments appear. There is now a definite commissure between the fingers, although considerable webbing remains at their base. All the muscles are present and are composed of muscle fibers. Figure 3 illustrates this stage. Ossification of the metacarpals and phalanges begins in from the seventh to the twelfth week. The interdigital commissure rapidly deepens after this period.

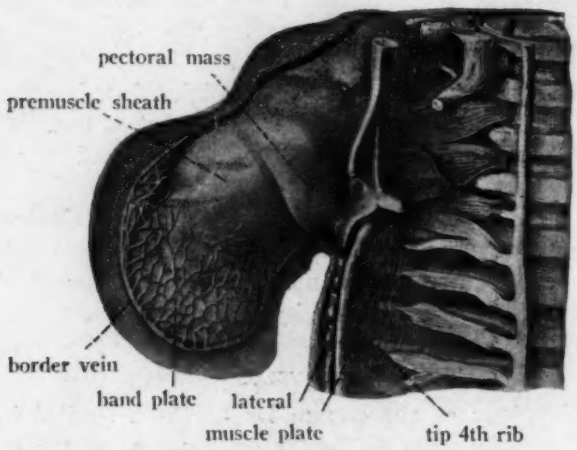

Fig. 1.—Hand plate in a 4½ weeks' embryo (Lewis). The border vein is present, but there is no evidence of differentiation in the hand plate.

The foot is developed in a manner similar to that of the hand. The posterior limb bud appears during the third week as a projection from the wolffian ridge opposite the twenty-first to the twenty-sixth spinal segments. In general, the development of the structures of the posterior limb occurs about one week later than that of the corresponding parts of the arm. Most of the main structures of the posterior limb may be distinguished by the end of the seventh week.

COMPARATIVE ANATOMY

Straus [3] recently reviewed this phase of the subject and described syndactylism occurring in the primates, the insectivores, the rodents and

3. Straus, W. L.: The Nature and Inheritance of Webbed-Toes in Man, J. Morphol. & Physiol. **41**:427, 1925.

the primitive marsupials. Beddard [4] stated that in the last group mentioned, all of the family *Macropodidae,* including the kangaroo, normally have the second and third toes united by a web. Among the rodents, many of the aquatic forms, including the beaver, have toes completely or partially webbed. Many of the aquatic forms of insectivores, including the moles, have the toes normally united by a web. Among the more common primates, *Catarrhinae,* or Old World monkeys, shows the normal presence of webbing between the fingers and toes in the genus *Cercocebus.* The siamangs of Sumatra and the Malay

Fig. 2.—The hand and foot in a 5 weeks' embryo (Bardeen and Lewis). From the carpus five masses of condensed tissue project, which are the finger masses. Centers of increased condensation corresponding to the carpal bones are also present.

Peninsula normally have a web between the second and third toes, as shown in figure 4. Syndactylism has also been described occasionally in the orang-utan, the gorilla and the chimpanzee. In the insectivores and the rodents, this condition may be regarded as an adaption to an aquatic form of life. In some forms of the primates, as suggested

4. Beddard, F. E.: Mammalia, in Cambridge Natural History, New York, The Macmillan Company, 1902, vol. 10.

by Weidenreich,[5] this persistence of webbing may be an adaption to an arboreal existence.

PATHOLOGY

The deformities of the hand have been classified by Nichols [6] under three heads: (1) those depending on deficient development; acheiria (absence of the hand), ectrodactylism (absence of one or more digits), hypophalangism (absence of one or more phalanges); (2) excessive development; polycheiria, polydactylism, polyphalangism; (3) perverted

Fig. 3.—The hand and foot in a 7 weeks' embryo (Bardeen and Lewis). Development of the metacarpals and phalanges proceeds rapidly and ossification begins from the seventh to the twelfth week. The ligaments have appeared. There is a definite commissure between the fingers which deepens rapidly from this period. The development of the foot proceeds in a similar manner, but in general is about one week later than that of the corresponding part of the hand.

development; syndactylism, cleft hand, congenital constrictions, congenital dislocations, congenital neoplasms. From this classification, it will be noted that syndactylism may be considered merely a local arrest of normal development.

5. Weidenreich, F.: Der Menschenfuss, Ztschr. f. Morphol. u. Anthrop. 22:51, 1922.

6. Nichols, E. H.: Reference Handbook of Medical Sciences, New York, Buck, 1902, vol. 4.

In the congenital cases, in addition to the syndactylism, there may be malformation of the bones of the hands or feet. Lepoutre [7] reported an unusual case of this type with syndactylism and marked deformity of the bones of the hands and feet in a mother and her child. The child also showed an unusual forking of the tips of several fingers. Clark [8] reported a case of bilateral syndactylism of the two ulnar digits, with absence of the radial digits. The same condition was found in the patient's father and her two brothers. The patient in the case reported by Epstein,[9] with no family history of syndactylism, had a cleft right hand, with complete absence of the middle phalanx, and the other

Fig. 4.—Normal syndactylism in the foot of a Siamang ape (redrawn from Schultz). Note the partial fusion of the second and third toes.

fingers were webbed. The feet were cleft and the toes webbed, but the left hand was normal. Groves [10] reported a case of syndactylism in which the proximal phalanx of the middle finger was in a transverse position and attached to the second finger.

7. Lepoutre: Malformations congénitales des extrémites chez un enfant et chez sa mère, Rev. d'orthop. **10**:237, 1923.

8. Clark, W. E. LeG.: A Case of Hereditary Syndactyly, Lancet **2**:434, 1916.

9. Epstein, J.: Perodactylism, Syndactylism and Cleft Extremities in a Child, New York M. J. **9**:153, 1919.

10. Groves, E. W. H.: An Unusual Case of Syndactylism, Brit. J. Surg. **1**:143, 1913.

A case similar to that reported by Groves was found in our series. In this instance there was bilateral webbing of the fourth and fifth fingers with fusion of the terminal phalanges. Another patient with bilateral webbing of the third and fourth fingers showed fusion of the terminal phalanges on the right with bilateral duplication of the terminal phalanges of the fourth finger, the duplicated phalanges being fused at each end. In another case illustrating the association of bony deformity with syndactylism,, there was forking of the phalanges of the fourth finger of one hand and deformity of the same bones of the other hand.

Cases of syndactylism, associated with intra-uterine partial amputation of the fingers or toes, have been reported by Assali,[11] Deeg,[12] and Coleman.[13] These deformities were attributed by Deeg and Ehringhaus [14] to the presence of amniotic bands. These bands, however, have never actually been demonstrated. In more than 8,000 specimens entered in the Carnegie Embryological collection, Streeter [15] found eight fetuses demonstrating various stages of the phenomenon of intra-uterine amputation. There was no evidence in any of these of amniotic bands or adhesions. Occasionally, in macerated fetuses, rolls of macerated epithelium were found giving the appearance of constricting bands. Streeter, however, expressed the belief that neither the epithelial rolls nor the umbilical cord can account for the constrictions. Instead, he found localized areas of necrosis affecting the amputations, either by complete destruction of the part or by forming an annular area sufficiently extensive to cause the sloughing off of everything peripheral to it. In the process of necrosis there is a tendency toward the formation of strands of fibrinous tissue which may give the appearance of constricting bands. These are not, however, the primary cause of amputation, and they are not amniotic in origin. The active period of the tissue necrosis was found in the fetuses of from 12 to 20 weeks; in the second half of pregnancy, the process was found either as a completed amputation or in the stage of arrest with more or less complete healing of the area affected.

Daraignez, Massé and Subervie [16] reported a case of syndactylism

11. Assali, J.: Amputations digitales, syndactylie, extrodactylie et sillons congénitaux, détérminés par brides amniotique, J. de méd. de Bordeaux **51**:107, 1921.

12. Deeg: Zwei selten Falle von angeborenen Missbildungen, Beitr. z. klin. Chir. **126**:429, 1922.

13. Coleman, H. A.: Coexistence of Congenital Amputations and Syndactylism, J. A. M. A. **83**:1164 (Oct. 11) 1924.

14. Ehringhaus, O.: Zur Pathologie und Therapie der Syndactylie, Berl. klin. Wchnschr. **49**:421, 1912.

15. Streeter, G. L.: Personal communication to the authors.

16. Daraignez; Massé, L., and Subervie: Syndactylie et polydactylie, J. de méd. de Bordeaux **54**:363, 1924.

of one hand and both feet, with polydactylism of the feet. Syndactylism was present in the paternal grandfather, a brother and a child of the patient. In a similar case in our series, the patient had webbing of the third and fourth fingers of one hand and polydactylism of both hands and feet.

The association of syndactylism with acrocephaly has been reported in about forty cases. The cases up to 1926 were reviewed by de Bruin,[17] who found that the prognosis as to life was favorable, but that vision was frequently threatened. Only two of the patients were idiots, the remainder apparently being normal mentally. There is a huge, round, protruding skull above the level of the eyes, and exophthalmos is usually present. Most of the patients show no familial or hereditary features, but Weech [18] recently reported a case with almost identical deformity of the head, hands and feet occurring in a mother of 19 and her daughter of 11 months. It is probably due to a defect in the germ plasm, as in the case of simple syndactylism, rather than to externally operating causes. A case illustrating these associated deformities occurred in our series.

Dervaux,[19] reported an unusual case of syndactylism consisting of the union of the terminal portion of two adjacent fingers, which occurred in both hands. There was no fusion of the proximal ends of the fingers. One foot showed a similar deformity. There were no previous cases in the family history. There was a similar case in our series, with union of the distal ends of the second and fourth fingers of both hands over the top of the third finger.

INHERITABILITY

There are many cases in the literature and also in our series, 18 per cent, illustrating the importance of an hereditary factor in syndactylism, and we feel that our percentage would have been higher had it been possible to obtain accurate data on this point. In the majority of cases, however, the family history was negative in this respect. Straus [3] studied the mode of inheritance, as shown in a number of pedigrees assembled from the literature and from original cases, and concluded that there appear to be four different hereditary groups.

In the first group, which appears to be the most common, the character is a mendelian dominant. This is illustrated in figure 5.

17. DeBruin, J.: Acrocephalosyndactylism, Nederl. tijdschr. v. geneesk. **3**:2380, 1925; abstr., J. A. M. A. **86**:456 (Feb. 6) 1926.

18. Weech, A. A.: Syndactylism and Acrocephaly, Familial, Bull. Johns Hopkins Hosp. **40**:73, 1927; abstr., J. A. M. A. **88**:1677 (May 21) 1927.

19. Dervaux: Syndactylie terminale des mains et syndactylie d'un pied, Bull. Soc. d'obst. de Paris **12**:316, 1909.

The example in the second group, figure 6, shows the character to be either a recessive in generation one for both parents, or to arise as a mutation in generation two, where it is a mendelian or sex-linked dominant.

In group three, the character is a mendelian or sex-linked recessive, figure 7. An example in our series also illustrates this type of inheritance, figure 8.

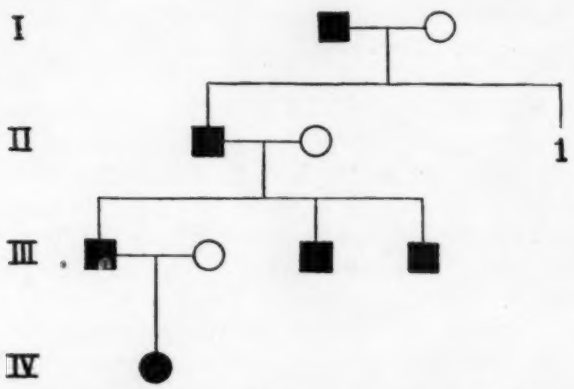

Fig. 5.—Pedigree showing syndactylism as a dominant mendelian character (Straus). The squares indicate males; the circles, females. The solid figures denote the presence of syndactylism; the open figures signify its absence. Each horizontal line represents one generation.

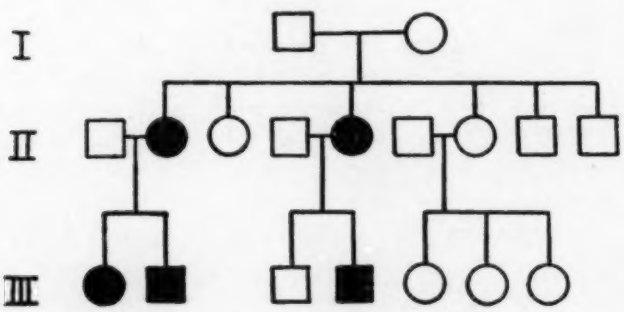

Fig. 6.—Pedigree showing syndactylism as a recessive, or arising as a mutation in generation II (Straus).

The fourth group consists of the case reported by Schofield,[20] in which the character of syndactylism is inherited by all the males of the family but never by the females, figure 9. It was pointed out by

20. Schofield, R.: Inheritance of Webbed-Toes, J. Hered. **12**:400, 1921.

Castle [21] that this character follows the distribution of the Y chromosome. Schmidt [22] found a similar type of transmission of an exclusively male character in the fish *Lebestos reticulatus*. This coincides with Painter's [23] work indicating an X-Y sex-determining pair of chromosomes.

Straus [8] also reported a case of syndactylism occurring in one of a pair of otherwise identical twins.

From a study of the pedigrees of families with syndactylism, Schultz [24] concluded that the character apparently never skips a

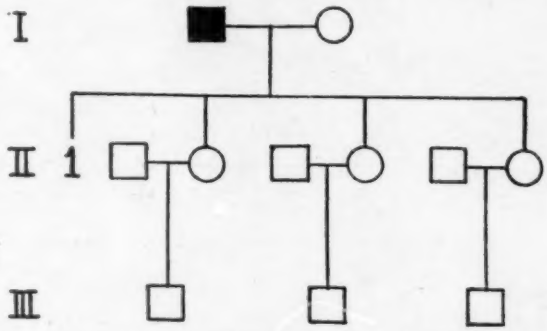

Fig. 7.—Pedigree showing syndactylism as a mendelian or sex-linked recessive (Straus).

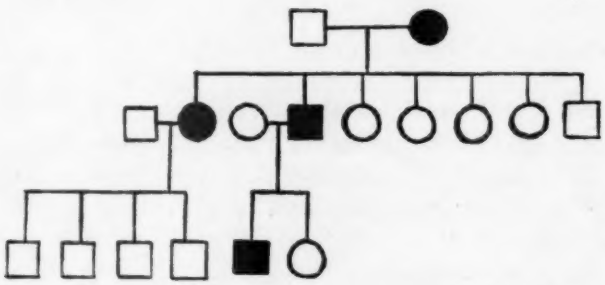

Fig. 8.—Pedigree of a case in our series, showing syndactylism as a recessive character.

generation and the persons who are free from the condition will probably have normal children. It appears that the female is less likely to transmit the condition and is also less likely to inherit it.

21. Castle, W. E.: Further Data on Webbed-Toes, J. Hered. **14**:209, 1923.
22. Schmidt, quoted by Castle, W. E.: A New Type of Inheritance, Science **53**:339, 1921.
23. Painter, T. S.: The Y-Chromosome in Mammals, Science **53**:503, 1921.
24. Schultz, A. H.: Zygodactylia and its Inheritance, J. Hered. **13**:113, 1922.

INCIDENCE

The incidence of syndactylism has been studied by Schurmeier,[25] who found 8 cases among 20,000 men examined. An analysis of cases in the literature shows the condition to be more common in males, 63 per cent, compared to 37 per cent in females. In our 50 cases the ratio was 68 per cent males to 32 per cent females.

SUMMARY OF CASES

Our series of 50 cases may be summarized as follows: males, 34 or 68 per cent; females, 16 or 32 per cent; color, white, 46 or 92 per cent; black, 4 or 8 per cent; family history of similar deformity, 9 or 18 per cent; no family history, 41 or 82 per cent.

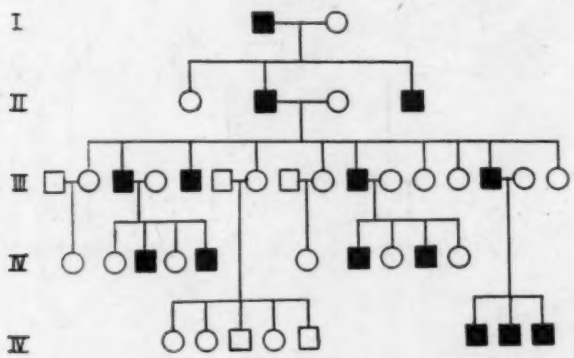

Fig. 9.—Pedigree showing syndactylism as a sex-linked character (Straus).

For convenience we shall separate the cases into three general groups: Group 1, fusion of the fingers alone; Group 2, fusion of the toes alone; Group 3, fusion of the fingers and toes.

Group 1.—Fingers alone, 30 cases, 60 per cent.

Second and third fingers: Right incomplete, 1; left complete, 1; left incomplete, 2; bilateral complete, 1.

Third and fourth fingers: Right complete, 3; left complete, 2; bilateral complete, 5; bilateral incomplete, 1; right incomplete, left complete, 1.

Second third and fourth fingers: Left complete, 2; bilateral complete, 1.

Second, third, fourth, and fifth fingers: Bilateral complete, 1.

Third, fourth and fifth fingers: Bilateral complete, 1.

Fourth and fifth fingers: Left complete, 1; bilateral complete, 1.

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25. Schurmeier, H. L.: Congenital Deformities in Drafted Men, Am. J. Phys. Anthrop. **5**:51, 1922.

First, second, third, fourth and fifth fingers: Right complete, 1; left hand, first and second, also fourth and fifth, 1.

First, second, also fourth and fifth fingers: Left, incomplete, 1.

Unsymmetrical bilateral fusions: Right hand incomplete; second and third; left hand incomplete, fourth and fifth, 1.

Right hand complete of stumps of the third and fourth; left hand complete, fourth and fifth, 1.

Right hand complete, third and fourth; left hand incomplete, second and third, 1.

Right hand, second to fourth over third; left hand, second to fourth over third, and fourth to fifth, 1.

Group 2.—Toes alone, 11 cases, 22 per cent.

Second and third toes: Right complete, 1; right incomplete, 2; left complete, 1; bilateral incomplete, 5.

Third and fourth toes: Bilateral incomplete, 1.

Second, third, fourth and fifth toes: Bilateral incomplete, 1.

Group 3.—Fingers and toes, 9 cases, 18 per cent.

Bilateral complete, third and fourth fingers; bilateral incomplete, second and third toes, 1.

Right hand complete, third and fourth fingers, left hand complete, third, fourth and fifth fingers; right foot incomplete, second and third, left foot complete, second and third toes, 1.

Bilateral complete, second and third fingers; bilateral complete, second, third and fourth toes. 1.

Bilateral complete, second and third fingers; right foot, incomplete second and third toes, left foot complete, second and third toes, 1.

Bilateral complete, second to fifth fingers; bilateral complete, first to fifth toes, 1.

Right hand complete, third and fourth fingers, left hand incomplete, second and third fingers; right foot complete, fourth and fifth toes, 1.

Left hand complete, third and fourth fingers; bilateral incomplete, second and third toes, 1.

Right hand incomplete, second and third fingers, left hand complete second and third fingers; right foot complete, fourth and fifth toes, 1.

Right hand complete, fourth and fifth fingers; right foot incomplete, second and third toes, 1.

Concurrent Congenital Deformities.—In a case of complete fusion of the second and third fingers of the left hand, the fourth and fifth fingers with their metacarpal bones were missing.

In a case of complete fusion of the second, third and fourth fingers of the left hand, there was arrested development of the entire hand, and the middle phalangeal bones of the fused fingers were missing.

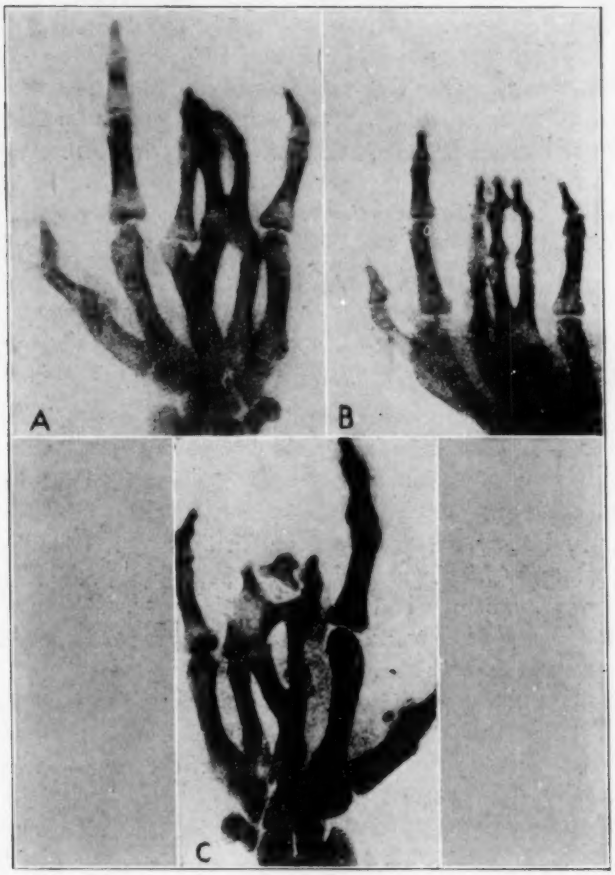

Fig. 10.—Bonnet and Trèves' (Syndactylia and Polydactylia, Bull. et mém. Soc. de chir. de Paris **20**:677, 1928) case, illustrating the inheritability of syndactylism. *A* and *B* show same hand, *C*, the other hand. The plates show the hands of a girl, aged 19, with a bilateral complicated type of syndactylism associated with polydactylism. The patient had two brothers and eight sisters. Three of the sisters presented the same malformation, as did all others in the family who were affected. The mother, the aunt and the female cousins had the same deformity, but the two maternal uncles were normal. From this it can be seen that in the last two generations only the women were affected, but in the preceding generation one finds the same malformation in the maternal grandfather, certain of his brothers and some cousins of both sexes. The patient said that she had been told that the same malformation had existed in the family for six or seven generations. A normal female child was subsequently born to the patient.

In a case of incomplete fusion of the second and third fingers of the left hand, there was arrested development of the entire hand and the second phalangeal bones of the fused fingers were much shortened.

In a case of complete fusion of the thumb and all the fingers of the right hand, the middle phalangeal bones of the second, third, fourth and fifth fingers were missing.

In two cases of complete fusion of the second and third toes, one of the right foot and the other of the left, the second phalangeal bones were elongated and there was a tumor made up of small closely packed lobules of fat, involving the sole of the foot close to the root of the toes.

In a case of bilateral fusion of the second and fourth fingers over the third there had been partial intra-uterine amputation of the third finger of the left hand and also of the terminal phalanges of the first and second toes of the right foot.

Fig. 11.—Partial bilateral syndactylism of the complicated type. The hands of a girl, aged 3 years, with no family history of syndactylism. There had been partial bilateral syndactylism of the ring and middle fingers. Note the distortion of the fingers and the unusual development of bone. This child had been operated on several times before coming under our care and dense scar tissue increased the deformity and interfered with function. Excision of the scar, readjustment of the bones and grafting the denuded surfaces with whole thickness grafts considerably improved function. In this case the original operative work was done too early and the scar contracture markedly increased the lateral deformities.

In a case of bilateral fusion of the second to the fifth fingers and of all the toes, there was also acrocephaly and there had been intra-uterine amputation of the left thumb.

In one case in which there was complete fusion of the third and fourth fingers of the right hand, there was a hydrocele.

In one case, there was a hemangioma of the scalp.

In one case with complete fusion of the stumps of the third and fourth fingers of the right hand and with complete fusion of the fourth and fifth fingers of the left hand, the phalanges and metacarpals of the

first and second fingers, the phalanges of the third finger and the middle and terminal phalanges of the fourth finger of the right hand were missing. On the left hand, the phalanges and metacarpal bones of the first finger were missing, as were the phalanges of the second finger and all but the proximal portion of the proximal phalanx of the third finger. There were also bilateral crabclaw cleft feet, with the phalanges and metatarsals of the second, third and fourth toes missing.

In a case of incomplete fusion of the second and third toes of the right foot, there was a bifid thumb on the right hand.

In one case of bilateral fusion of the second, third and fourth fingers, there was also a bilateral talipes equinovarus and a deep con-

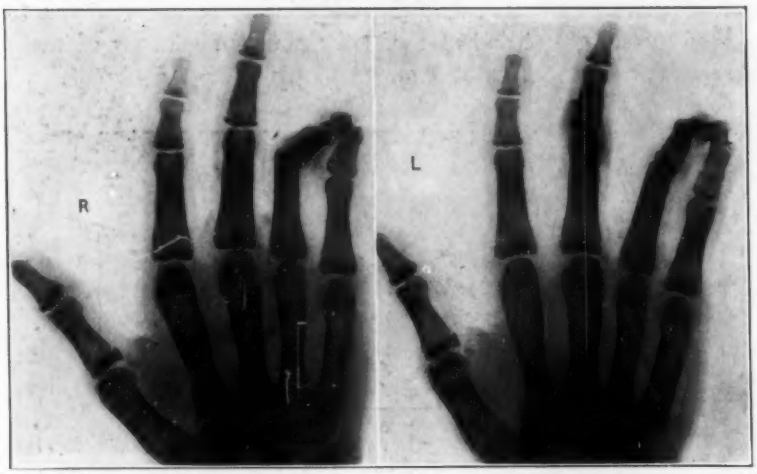

Fig. 12.—Complete bilateral syndactylism of the complicated type. X-ray pictures of the hands of a boy, aged 17, with no family history of syndactylism. Note the unusual fusion and displacement of bone of the terminal phalanges of the ring and little fingers of both hands.

stricting band 0.5 cm. wide, around the lower third of the right leg above the ankle.

In a case of incomplete fusion of the second and third fingers of the right hand, there was also a large umbilical hernia.

In a case of incomplete fusion of the second and third fingers of the right hand and of the fourth and fifth fingers of the left hand, there was tongue-tie and an abnormality of the lower jaw, also bilateral talipes equinovarus.

In one case of complete fusion of the third and fourth fingers of the right hand, there was a congenital cleft of the palate and bilateral talipes equinovarus.

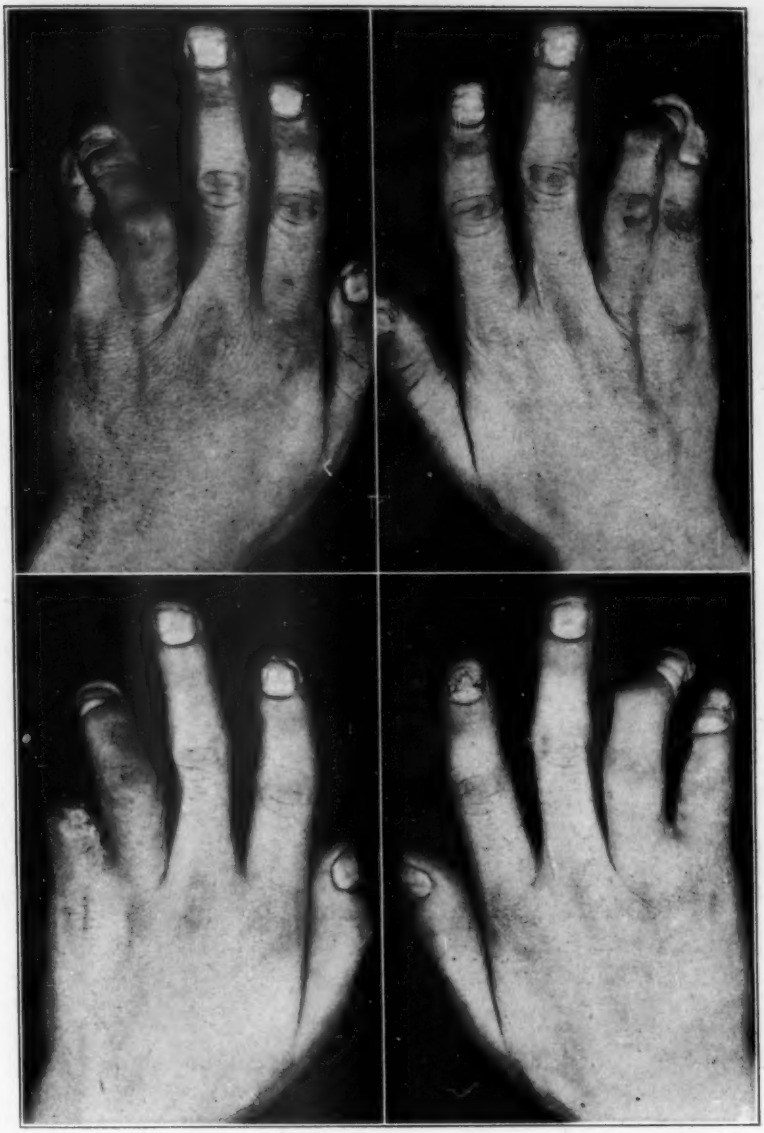

Fig. 13.—Photographs of the hands shown in figure 12. The bilateral fusion of the fingers can be well seen. The marked distortion of the fused fingers is probably due to the long period during which the condition has been allowed to remain unrelieved and illustrates the importance of the early separation of fused fingers of unequal length so that each finger may be unrestricted in its growth. Without doubt, this distortion would have been much less marked if separation had been done as soon as the unequal growth of the fingers became evident. Division of the webs with closure of the skin edges by suture, in another clinic, resulted in gangrene, necessitating amputation of the distal phalanx of the left little finger. It was necessary subsequently to shorten the phalanx, remove the scar tissue and skin graft the remaining defect before a satisfactory stump was finally obtained. The right hand shows the separation of the fingers nearly completed. The commissure is higher than normal and should be lowered. When this is done, full separation of the fingers will be possible. This case illustrates the importance of preserving the blood supply and the danger of approximating the skin edges under too much tension.

In a case of complete fusion of the third and fourth fingers of the left hand and bilateral incomplete fusion of the second and third toes, there were double great toes on both feet.

In a case of complete fusion of the first and second and of the fourth and fifth fingers of the left hand, there was a supernumerary little finger on the left hand.

In a case of complete fusion of the second and third toes of the right foot, there was right talipes equinovarus.

In a case of fusion of the fourth and fifth fingers of the left hand, there was a lymphangioma of the right foot.

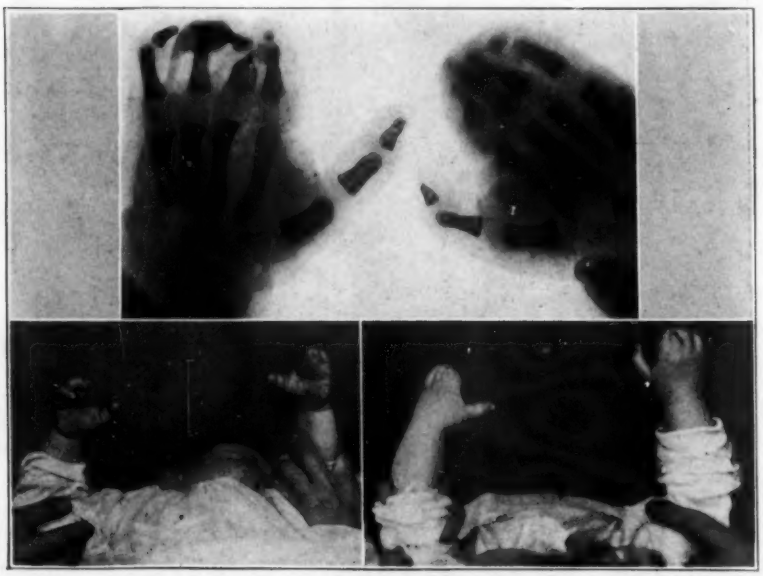

Fig. 14.—Bilateral complicated syndactylism of the hands in a girl, aged 1 year, who had no family history of syndactylism. The head was quite large. Right hand: The shortened and thickened second finger was united to the end of the fourth finger over the top of the middle finger. The proximal phalanges of the fourth and fifth fingers were fused. Left hand: The third finger was missing except for a portion of the first phalanx; over this the second and fourth fingers were fused. The fourth and fifth fingers were also fused, and the left hand had the appearance of a mitten. The first and second toes of the right foot were missing. It is probable that the fusion of the ends of the second and fourth fingers over the middle finger of each hand was due to the growing together of two raw surfaces which occurred during the process of intra-uterine amputations and that this was not caused by an arrest in normal development. Operative treatment: The fused ends of the second and fourth fingers were divided to allow growth and the raw surfaces were grafted.

In a case of bilateral incomplete fusion of the third and fourth toes, there was bilateral synostosis of the first joint of the fifth finger.

In a case of complete fusion of the fourth and fifth fingers of the right hand and incomplete fusion of the second and third toes of the right foot, there were bilateral supernumerary fifth fingers and toes.

REVIEW OF OPERATIVE PROCEDURES USED IN THE TREATMENT FOR SYNDACTYLISM

In dealing with the treatment for webbed fingers, it is advisable for the surgeon to be familiar with the different types of operations

Fig. 15.—Syndactylism associated with arrested development, in a white child, aged 5½ years. There was a history of a first cousin of her maternal grandmother having had webbing of the third and fourth fingers. This plate is shown to illustrate the fact which we have noted several times in our series that associated with syndactylism there may be arrested development of the entire hand. There is incomplete fusion of the second, third and fourth fingers. Note the size of all the bones as compared with the normal hand, also the marked shortening of the second phalangeal bones. In this case the fingers were completely separated and the commissures formed; every effort is being made to stimulate the growth of the hand. The function of the individual fingers is perfect.

that have been used at various times, as he may be able to utilize points from more than one operative method in dealing with the particular case under consideration.

A review of the literature reveals numerous methods that have been advocated for relief from syndactylism, and we shall outline briefly some of the more important of those which have appeared during the last one hundred and twenty-five years and shall comment on them.

Rudtorffer's Operation — Velpeau's Operation.—During the earliest times simple division of the web was practiced, but this proved unsatisfactory as it was almost always followed by a growth of scar tissue

Fig. 16.—Roentgenograms of a white boy, aged 11, shown to illustrate a marked case of bilateral syndactylism. Right hand: The second and third fingers are partially fused and although the web does not extend to the terminal phalanx, there is marked flexion of the third finger which can be noted in this figure and also in figure 17. Left hand: The third and fourth fingers are completely fused, the nails of the first and second phalanges being also joined. Note the bone distortion and the position of the phalangeal bones. In trying to restore the fingers in a case of this type, the greatest care is necessary and the only method which promised any result is the use of a whole thickness graft to cover the raw surfaces and also form the commissure. In such a case, if there is any doubt about the circulation, it is advisable to separate only the distal portion first and later complete the work.

across the commissure, contraction of the scar and at least a partial return of the original deformity. Rudtorffer,[26] in 1801, modified this

26. Rudtorffer: Abhandlung über die Operation eingeoperierter Brüche nebst einem Anhang, Vienna, J. V. Degan, 1810, vol. 11, p. 478.

procedure by making a tunnel, from the dorsal to the palmar aspect, at the base of the web. A leaden thread was introduced through this opening and was kept in place till the tunnel was lined with epithelium; this cicatrized fistula formed the floor of the new commissure. The web was then divided down into the lumen of the tunnel, and the fingers were kept separated until healing was complete. This procedure was moderately successful in the cases with a thin wide web. Later operators

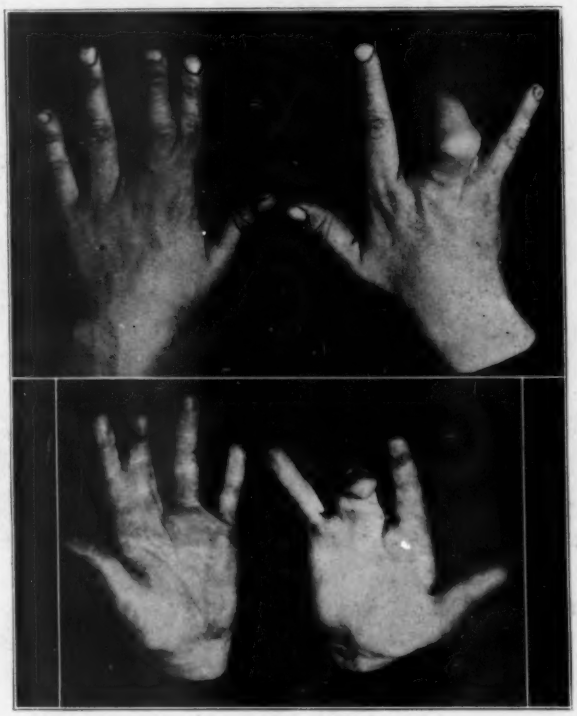

Fig. 17.—Same patient as in figure 16. Note the amount of extension possible in the fused fingers.

substituted a silver wire, an india rubber cord or a glass tube for the leaden thread. Velpeau [27] made use of Rudtorffer's procedure, but improved on it by suturing the edges of the skin along each finger after division of the web down to the epithelialized tunnel.

This method is far from satisfactory, as the commissure thus formed is usually narrow and is liable to split; in fact, the procedure is now seldom used by any one who is familiar with the modern surgical treatment for fused fingers.

27. Velpeau: Operative Surgery, Townsend and Mott, New York, S. S. & W. Wood, 1847, vol. 1, p. 386.

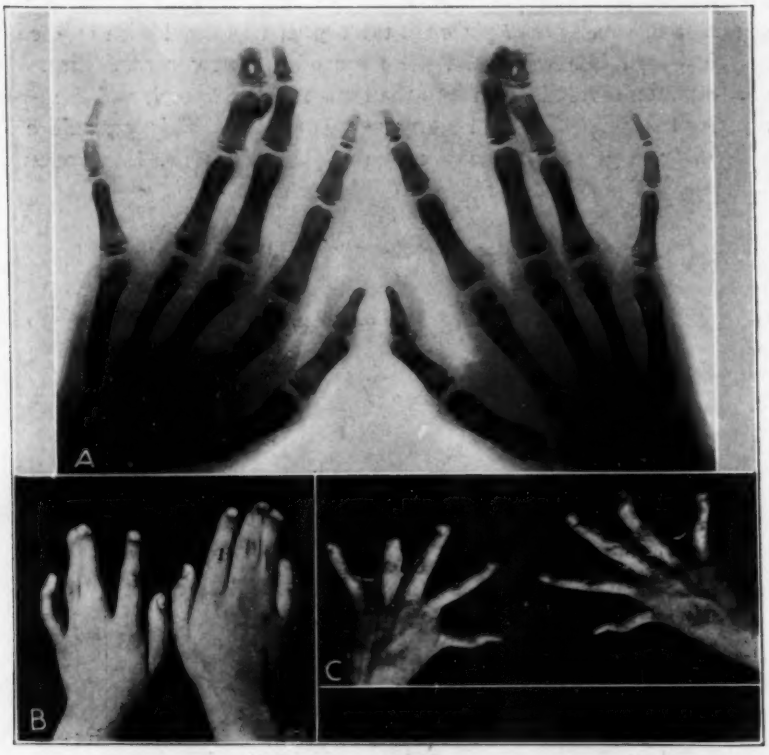

Fig. 18.—*A*, complete bilateral syndactylism of the complicated type in a girl, aged 6, with congenital bilateral fusion of the ring and middle fingers and with bony union of the terminal phalanges of these fingers on the right hand. There was a family history of similar developmental deformities in the maternal great grandfather, both hands; in the maternal grandfather, right hand, and in the mother, right hand. *B*, note the double terminal phalanx of the left ring finger and the abnormal bony growth on the radial side of the second phalanx near the joint. There is also a double terminal phalanx on the right ring finger, which is fused with the terminal phalanx of the middle finger. This is rather an unusual type of bone fusion. It can be noted in *B* that the nails on the right hand, where the bony fusion is closest, have a distinct groove separating them, while on the left hand where the fusion of the bones is lacking, the nails are closely fused. The lateral distortion of the terminal phalanges and the slight angling of the joints are to be noted; this is due to the fusion of fingers of unequal length. Early separation of these terminal phalanges would probably have minimized the lateral tilting. *C*, ten years after operation: Great improvement followed the separation of the fingers but it can be noted that there is still some distortion of the terminal phalanges of both ring fingers. In this case the commissures could be deepened considerably and possibly the terminal phalanges straightened. The function of the hand is excellent and the patient has hesitated to undergo further operative work.

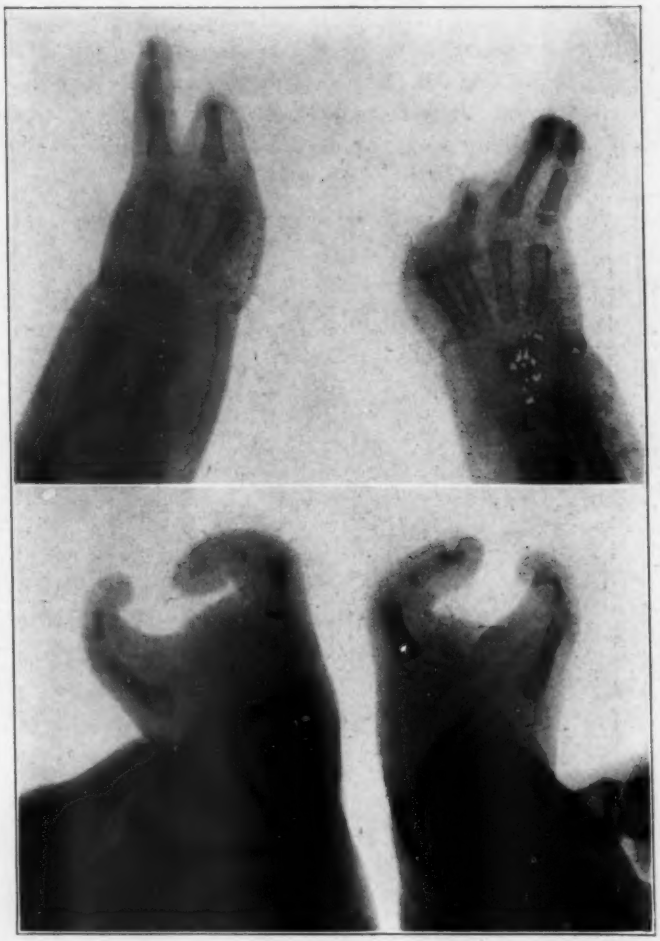

Fig. 19.—Syndactylism, missing metacarpals and phalanges and crabclaw feet in a white child, aged 18 months, with a history of the mother having complete unilateral syndactylism of the second and third toes of the left foot. This case is interesting from the fact that on the right hand the first and second fingers with their metacarpal bones are missing, also the phalangeal bones of the third finger and the two distal phalanges of the fourth finger, although there is apparent fusion of the stumps of the third and fourth fingers. On the left hand, there is complete fusion of the fourth and fifth fingers. The thumb with its phalanges and metacarpal bone is missing, as are the phalanges of the second finger and with the exception of a small fragment, those of the third finger. Both feet are of the typical crabclaw cleft type. In this case, the first step was the preliminary separation of the fourth and fifth fingers of the left hand to allow normal growth.

Zeller's Operation.—In 1810, Zeller [28] introduced the flap method. He raised a short V-shaped flap on the dorsal aspect of the root of the web, the base of the flap corresponding to the position of the normal commissure (fig. 20). After division of the rest of the web, the apex of the flap was drawn through between the fingers and sutured to the palmar aspect, thus forming and lining the commissure. The tendency for sloughing to occur at the tip of the V-shaped flap led

Fig. 20.—Same patient as in figure 19.

Dieffenbach [29] to adopt a flap of quadrilateral outline which was utilized in the same way. Another modification of this operation was described by Norton,[30] who made use of two triangular flaps, one from

28. Zeller: Ueber der ersten Erscheinungen venerischen Localkrankheit, Vienna, J. G. Binz, 1810, p. 109.

29. Dieffenbach, F. J.: Chirurgische Erfahrungen besonders über die Wiederherstellung zerstörter Teile des menschlichen Korpers nach neuen Methoden, Berlin, T. C. F. Enslin, 1834.

30. Norton, A. T.: A New and Reliable Operation for the Cure of Webbed-Fingers, Brit. M. J. **2**:931, 1881.

the dorsal and the other from the palmar aspect, which were carried between the fingers from opposite directions to form a new commissure. The principle of Zeller's operation was also used in the method of Deces and that of Morel-Lavalle.[31] The use of a flap, either single or double, for forming the commissure was a distinct advance in the treatment for this deformity, and we frequently use it in one form or another with considerable satisfaction.

Didot's Operation.—This method has been attributed to Didot,[32] Diday [33] and Nélaton.[34] Didot described the method in 1850, while an

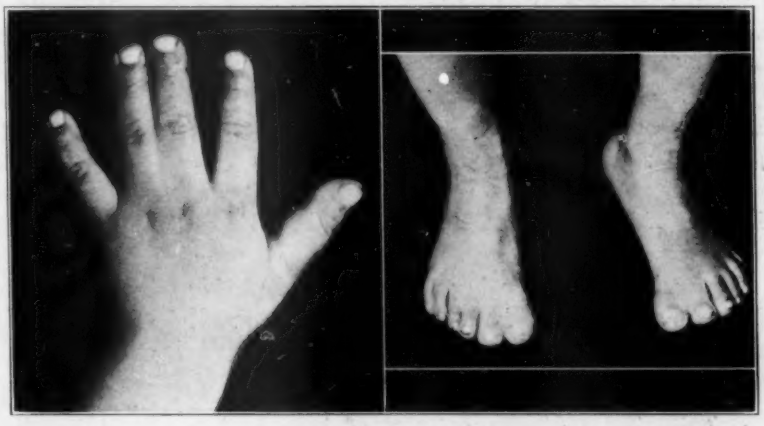

Fig. 21.—Syndactylism, associated with double great toes, in a negro boy, with no family history of similar trouble. There is almost complete fusion of the third and fourth fingers of the left hand, also bilateral incomplete fusion of the second and third toes and bilateral double great toes. Note that the terminal phalanges of the webbed fingers are not completely adherent and that the separation present has prevented the marked distortion which ordinarily would have occurred had the fusion been complete between these fingers. It can be seen, however, that there is considerable pull exerted by the third finger, and further separation was advisable in order to avoid lateral curving of the digits before the formation of the commissure and the final complete separation of the fingers. As far as the feet are concerned, the webbed toes should not be disturbed. Except for the width of the feet there is no need for interference with the double great toes in this particular case.

abstract of Diday's paper appeared in the same year (fig. 21). Nélaton's article on the subject was not published until 1884. The principle

31. Morel-Lavalle: Cas de syndactylie chez un homme, Compt. rend. Soc. de biol. **1**:166, 1849-1850.

32. Didot, A.: Acad. roy. de Belg. **9**:351, 1849-1850.

33. Diday, A.: J. f. Kinderkrankht. **15**:470, 1850.

34. Nélaton, A.: Éléments de pathologie chirurgicale, Paris, Germer-Baillière et Cie, 1884, vol. 6, p. 1020.

consists of the production of two short, broad-based quadrilateral flaps, the first with its pedicle on the dorsum of one of the united fingers and the second with its pedicle on the palmar aspect of the other finger. The breadth of the flaps corresponds to the length of the web, and their length should correspond to the width of the raw surface each flap has to cover. After the flaps have been raised, the remaining tissue uniting the fingers is divided in the midline, interference with the circulation being avoided if possible. The flaps are then swung around to cover the raw surface of the finger to which each is attached, and are sutured in place. On paper, this is an attractive procedure, but in actual practice we rarely use the method, especially when the fingers are closely fused, as the flaps are seldom sufficiently long to cover the defect. Consequently, when the closure is made, care must be taken to avoid too much tension on the flaps, as this in some instances may obstruct the circulation sufficiently to cause gangrene of the finger. In this type of operation, the fingers are separated and theoretically covered, but no provision is made for the formation of a true commissure. This may be formed, however, by a skin graft or a flap from a distant part.

In certain instances, when there is sufficient skin to assure flaps by Didot's method which are long enough to be sutured without tension, the preliminary formation of a skin-lined tube at the base of the web to form the commissure might be considered.

Agnew's[35] *Operation (1883).*—This procedure is used when the web is quite wide, and it is really a modification of Zeller's operation, but differs from the latter in having the V-shaped flap extend to the distal margin of the web. The flap is raised from the dorsum of the web, with its base at the metacarpophalangeal joint. After division of the remaining portion of the web, the flap is sutured to the palm, and the lax skin of the palmar surface is used to close the raw surfaces of the fingers (fig. 22). In using this procedure, we have found that a blunt pointed flap is more practical than one with a sharp point.

Félizet's[36] *Operation (1892).*—This operation is almost indentical with the modification of Zeller's operation practiced by Norton. Two small triangular flaps are raised at the base of the web with their apexes pointing distally. One flap is on the palmar and the other on the dorsal aspect of the hand (fig. 23). After the web is divided, the flaps are drawn between the fingers and are sutured side by side to form the new commissure. This procedure insures the formation of a broad,

35. Agnew, D. H.: Principles and Practice of Surgery, Philadelphia, J. B. Lippincott Company, 1889, vol. 3, p. 371.

36. Félizet, G.: Rev. d'orthop. **3**:49, 1892.

Fig. 22.—Incomplete simple unilateral syndactylism of the right hand and foot, associated with bilateral polydactylism of the hands and feet, in a boy, aged 6 years, who had a family history of syndactylism in the father, a sister, a granduncle and a cousin on the paternal side. There is fusion of the fourth and fifth fingers of the right hand which extended nearly to the nails. There is incomplete fusion of the second and third toes of the right foot. There are also bilateral supernumerary fifth fingers and toes. Roentgen examination showed the bones to be normal. The web was divided, and the skin which was slack was sutured, thus covering both fingers. The commissure was made by utilizing the skin of the supernumerary fingers. A perfect functional result was obtained. The age of this patient was about right to begin operative work.

thick commissure, and with modifications made to suit conditions it is useful. The raw surfaces may be closed by sutures if the skin is lax, otherwise they must be grafted.

Bidwell's[37] *Operation (1913).*—This operation is practically a combination of Zeller's and Didot's operations and consists of the production of a V-shaped flap on the dorsum at the base of the web and a lateral flap of the Didot type on the dorusm of one of the fused fingers. A straight incision is made through the palmar portion of the web to insure normal skin on the palmar surface of the fingers. The dorsal V-shaped flap is sutured to the palm, after division of the web, to make the commissure, and the lateral flap is sutured to the edge of

Fig. 23.—Zeller's operation for syndactylism. Zeller, in 1810, was the first to suggest the use of a flap to form the commissure. In this drawing the webs were lax and thin. The dotted lines indicate the incisions. Note the short pointed flap outlined at the proximal end of the web. The fingers were separated, the flap was raised and drawn between the fingers. The tip was then sutured to the incision on the palmar surface, thus forming the commissure.

the skin of the palmar aspect of the finger to which it is attached (fig. 24). This leaves an extensive raw area on the dorsum and inner aspect of one finger, which should be covered by a skin graft. The procedure may even be used in cases in which the web is very narrow, and should be borne in mind, as the commissure is formed with a flap and one finger is covered with skin, leaving only a single area to graft. The choice of fingers to cover with the flap is important.

37. Bidwell, L. A.: Minor Surgery, ed. 2, New York, William Wood & Company, 1913, p. 90.

Faniel's[38] *Operation (1911).*—This is a modification of Didot's operation in which a Z-shaped incision is made on the dorsal and palmar surfaces of the web, in place of the usual quadrilateral flaps (fig. 25). Each Z is resolved into two V-shaped flaps on the front and back of the web, and these are brought around and sutured to form the inner surface of each finger. The tips of the V-shaped flaps are likely to slough if there is any undue tension.

Tubby's Operation (1912).—Tubby[39] made use of the principles of Rudtorffer, Zeller and Didot, and his operation is practically identical with one of the methods previously described by Felizet. Two flaps are cut at the base of the web, the palmar with its base toward the tips of the fingers and the dorsal in the opposite direction (fig. 26). The soft parts between the flaps are removed, and each flap is drawn through this opening and sutured so as to line it as completely as possible. A

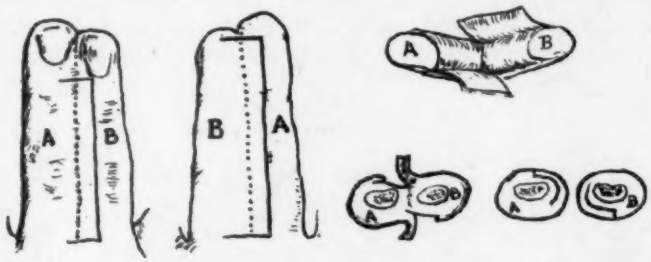

Fig. 24.—Didot's operation for syndactylism: The drawing shows the fusion of two fingers, *A* and *B*. The solid line indicates the incision made in raising the palmar flap with its base on *B*. A similar flap is raised on the dorsal surface of the fingers with its base on *A*. The dotted line shows the site of the midline separation of the fingers after the flaps are raised. After the fingers have been separated, the flap with its base on *B* is brought around and sutured to fill the defect on *B*, which is left by raising the flap with its base on *A*. The flap on *A* is used in a similar manner to fill the defect on this finger. The transverse sections indicate the manner in which this procedure is carried out.

glass rod is then passed through the opening and is held in place by supports projecting from a metal cuff fastened about the wrist. When the foramen has completely healed, the second stage is carried out as in Didot's operation, and the glass rod is again placed in position to insure the maintenance of the commissure in its normal location. This seems the rational place to use Didot's operation, if there is sufficient

38. Faniel, H.: Syndactylie, modification du precédé de Didot, Scalpel, Liège **64**:254, 1911.

39. Tubby, A. H.: An Operation for Webbed Fingers, Brit. M. J. **2**:1464 (Nov. 23) 1912.

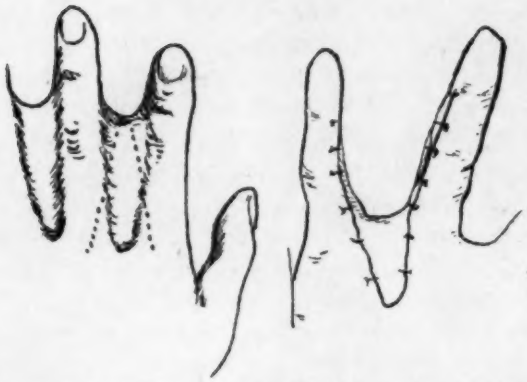

Fig. 25.—Agnew's operation for syndactylism: The drawing shows a lax web. The dotted line indicates the incision made to form the flap. Note that the flap is long and extends to the margin of the web. The drawing shows the flap much more blunt than that originally used by Agnew. The flap is raised and after a midline separation of the fingers; it is brought forward between the fingers to form the commissure and is sutured in position. The skin on the fingers is closed by sutures.

Fig. 26.—Félizet's operation for syndactylism (Davis, J. S.: Plastic Surgery, Philadelphia, P. Blakiston's Son & Company, 1919, p. 239). Two small triangular flaps, one from the palmar and the other from the dorsal surface, are raised from the base of the web with their apices pointing distally. The fingers are separated and the flaps are brought down and placed side by side and sutured, thus forming the commissure. If the skin on the fingers is lax the edges may be sutured, otherwise the defects left must be covered with whole thickness grafts.

skin to close without tension, as the commissure is formed before the fingers are released; however, we have seldom found it necessary to form a commissure by means of a permanent fistula.

Radulesco's[40] *Operation (1923).*—This operation is somewhat similar to Faniel's operation. The dorsal and palmar incisions are made in the form of an inverted question mark instead of a Z, the dorsal flap extending as low as the metocarpophalangeal joint, and the palmar flap not quite so low. This eliminates the sharp apexes that have a tendency to slough, and is an improvement over Faniel's procedure. The flaps are sutured in place to form the inner aspects of the fingers and also the commissure (fig. 27). The method is well worth bearing in mind and will be found useful. This operation, as well as that of

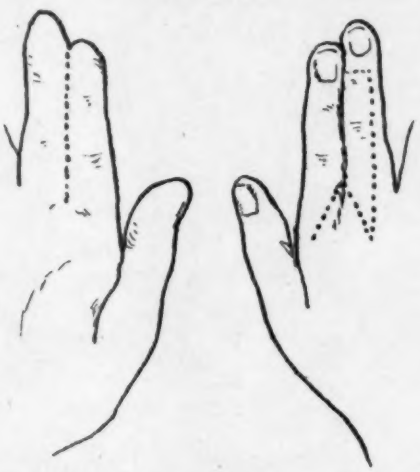

Fig. 27.—Bidwell's operation for syndactylism: The dotted lines indicate the incisions. The triangular flap at the base of the web is drawn forward after the fingers are separated and forms the commissure. Note the wide flap to be raised from the back of the middle finger which has its base on the dorsum of the index finger and which will be brought around to cover the defect on the index finger. This, of course, leaves a large uncovered surface on the middle finger which should be covered with a whole thickness skin graft.

Faniel, depends on the shifting of flaps cut in different ways, and the vitality of these flaps depends largely on whether or not they can be sutured without tension.

Villechaise's[41] *Operation (1927).*—This is a modification of the procedures of Didot and Agnew, applicable in cases in which there is a

40. Radulesco, A. D.: Un nouveau procéde operatoire digito-commissural comme traitement de la syndactylie congénitale, Rev. d'orthop. **30**:499, 1923; Abstr., Internat. Survey Surg., February, 1924, p. 257.

41. Villechaise, and Jean, G.: Quelques points de technique concernant la chirurgie de la syndactylie, Rev. d'orthop. **14**:241, 1927.

wide web between the fingers. In place of the dorsal V-shaped flap of Agnew, a palmar quadrilateral flap is raised, with its base at the metacarpophalangeal joint (fig. 28). When drawn between the separated fingers, this flap forms the commissure. In place of the dorsal and palmar finger flaps of Didot, two dorsal finger flaps are made to form the inner surface of the fingers. In cases in which there is a narrow web, a long pedunculated flap is raised, with its base at the metacarpophalangeal joint and its apex extending proximally along the dorsum of the hand. The web is then divided and the flap is swung around to cover the inner surface of one of the fingers. This procedure is also advocated by Forgue [42] (fig. 29). The difficulty is that no pedunculated flap as long as that shown in the illustration and with as narrow a pedicle can live in such a situation, unless it is carefully

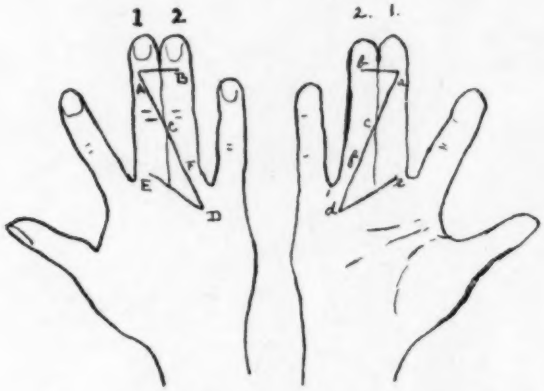

Fig. 28.—Faniel's operation for syndactylism: The drawing shows fusion of the third and fourth fingers, designated 1 and 2. A transverse incision *A-B* is made at the most distal point of the fusion. This includes half of the skin of both fingers. From *A*, an oblique incision, *C-D*, is made to the center of the base of finger 2, ending near the metacarpophalangeal joint. From *D* an incision is carried to the middle of the base of the proximal phalanx which ends a little higher than the level of the future commissure, a line from *E* to *F* being parallel to *AB*. This forms the flaps *BAC* with its pedicle on finger 2, and *CDE* with its pedicle on finger 1. The same incisions, reversed, are made on the palmar surface of the fingers and two other flaps thus formed. The four flaps are dissected up, the fingers are separated and the flaps are sutured into the positions into which they fall.

prepared as a delayed transfer of the double pedicled variety, with subsequent division of the outer pedicle. However, it might live as would a graft if it consisted of the skin alone, but in our opinion a

42. Forgue, L. D.: Syndactylie membraneuse congénitale du médius et de l'annulaire des deux mains operation, Arch. de méd. et pharm. mil. **27**:128, 1896.

whole thickness graft would be preferable, as it could be obtained without damage to the hand.

Stone's Operation (1908).—J. S. Stone[43] devised a method for covering the index and little fingers with skin in cases in which there is fusion of the second, third, fourth and fifth fingers. A dorsal longitudinal incision is made along the full length of the web between the ring and middle fingers, and transverse incisions are made on each side of this incision at the base and apex of the web, thus forming two dorsal quadrilateral flaps. The pedicles of these flaps are on the index and little fingers. The webs attached to the index and the little fingers are then divided, and the flaps on the dorsa of these fingers are swung around and sutured to the palmar aspect, thus covering these fingers with skin (fig. 30). The middle and ring fingers are still fused, but are denuded of skin on their dorsal surfaces. This raw surface may

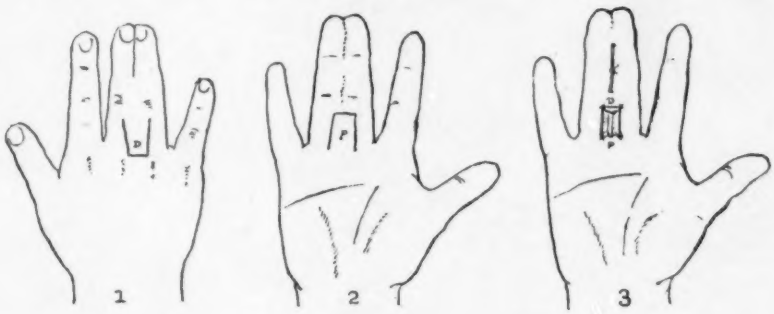

Fig. 29.—Procedure of Félizet (Berger and Banzet: Treatment of Syndactylism, Chir. Orthop., 1904, p. 278): 1 shows the incisions made outlining the dorsal flap *D* with its pedicle toward the tips of the fingers. 2 shows the incisions outlining the palmar flap with its pedicle toward the palm. 3 shows the buttonhole made between the fingers after the flaps are raised with the dorsal flap lining the distal end and the palmar flap the proximal end. The sides of the buttonhole are allowed to heal by granulation. By this procedure the commissure is formed. Note the elastic ligature above which is passed through the web and is tightly tied, which is eventually supposed to complete the separation but today is seldom, if ever, used. The formation of the commissure by this method is practically the same as that subsequently described by Tubby, but instead of using the elastic ligature, he utilizes Didot's method for covering the fingers.

be covered by a graft, a gauntlet flap or a pedunculated flap from the abdominal wall. This operation provides for the separation of two of the fingers and their being covered with skin flaps, but this is only the first step as wide commissures have to be formed before the fingers can function properly. The ring and middle fingers can subsequently be

43. Stone, J. S.: American Practice of Surgery, New York, Wm. Wood & Company, 1908, vol. 4, p. 634.

separated and at the same time a commissure formed either by the use of a flap of the intact skin, with grafting of skin when necessary, or by simple division of the web followed by lining the raw surfaces and forming the commissure with single whole thickness graft by the method described later. Stone's operation is based on Didot's quadrilateral flap method, but he secures both flaps from the back of the middle and ring fingers rather than one from the dorsal and one from the palmar surface. This leaves a single broad denuded area which is much easier to cover with a skin graft or flap than the narrower denudations that result when the flaps are raised from the front and back of the fingers to be covered. The utilization of the skin from the entire dorsal surface of the fused middle and ring fingers gives a flap of sufficient size to cover the fore and little fingers without tension.

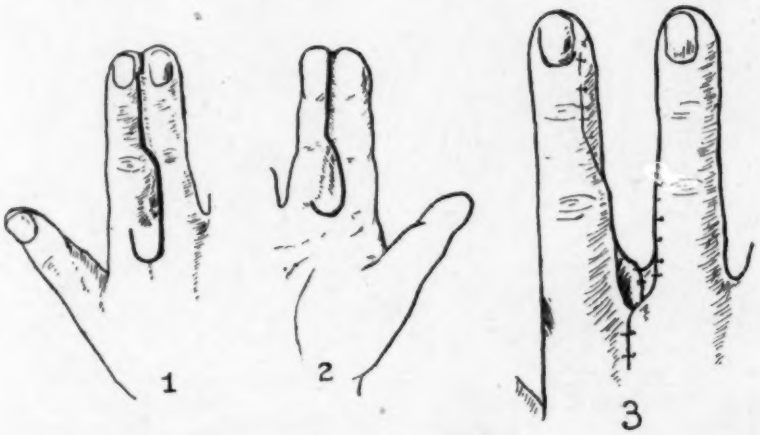

Fig. 30.—Radulesco's operation for syndactylism: 1 and 2, the dark lines indicate the incisions made in raising flaps which will cover in the fingers and also form the commissure. 3 shows the flaps sutured in place.

METHODS FOUND USEFUL BY AUTHORS IN THE TREATMENT FOR CONGENITAL SYNDACTYLISM

A glance at the summary of our series of cases and at the illustrations will give an idea of some of the varieties of the deformity, and will indicate clearly that the problem of reconstruction is far from simple. As a matter of fact, in certain instances complete restoration of normal function may be impossible.

Experience has shown us that no single operation has yet been developed which can be used in relieving all types of syndactylism. Each case must be studied carefully, and the method or combination of methods selected which will be most effective for the individual case. The cure of syndactylism, even in the simpler cases, is not as easy as

some of the drawings and operative descriptions would lead one to believe. In fact, a good result is a difficult matter to accomplish, and it is frequently necessary to operate several times before the desired outcome is obtained.

Most Suitable Age for Operation.—In the instances in which there is complete fusion of fingers of unequal length with coherence of the terminal phalanges on the same level, development is interfered with and marked secondary deformity will be produced unless the fingers are separated sufficiently to allow the independent unhindered growth of both fingers. This separation should be made as early as the inequality of growth becomes apparent, however young the child may be. We usually separate the fingers in the midline and cover the raw surfaces with a whole thickness skin graft. This procedure, which is all that should be done at this period, usually gives the fingers an opportunity to grow, and often prevents lateral bending of the phalanges.

Fig. 31.—Villechaise's operation for syndactylism: A palmar flap, *CABD*, is formed; then two dorsal flaps, *EFLK* and *GFLM*. The fingers are separated, and the flap *CABD* is carried backward between the fingers and sutured to form the commissure. Then the two dorsal flaps are brought forward and sutured to fill the defects on the fingers.

On the other hand, we feel that in the majority of cases, it is poor surgical judgment to operate for complete relief from this malformation and to attempt the formation of a wide commissure before the child is 6 or 7 years old. We say this advisedly as in the instances in which early complete operations have been done, here and elsewhere, it is almost always necessary to do them over again when the child grows older. We often see patients whose hands have been operated on several times for complete relief from syndactylism before they are 6 months old, and some of them are in such condition that it takes years of work and numerous operations to salvage the fingers so that they may become even partially useful. In several instances in which function could not be restored, we have had to amputate the deformed fingers.

Operative Treatment.—The key to the success of any operative procedure undertaken for relief from syndactylism is the formation of a satisfactory commissure between the fused fingers, and in order to

allow for subsequent shrinkage this commissure should be made somewhat deeper and wider than that between the normal fingers. When one is dealing with a web that does not hold the fingers closely together, or in other words with a lax web, several procedures may be tried. A useful method is to raise a long dorsal flap, which is much more blunt than that suggested by Agnew, and which has its pedicle toward the wrist on the level of the metacarpophalangeal joints. After a midline division of the palmar surface of the web down to the same level, a short transverse incision is made on each side, forming an inverted T. The flap is drawn forward between the fingers to form the commissure and is sutured to the transverse portion of the T. The skin on the fingers is then sutured. We use horsehair sutures exclusively in all of these cases. We find, however, depending on conditions, that shorter dorsal

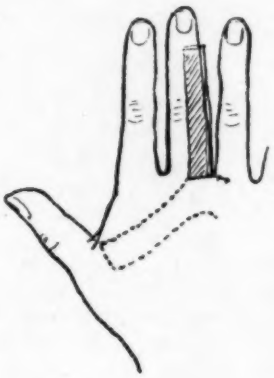

Fig. 32.—Forgue's operation for syndactylism (Villechaise and Jean): The dotted line shows the incision made in raising a pedunculated flap from the dorsum of the hand, to be used in covering the raw surface of one finger after division of the web. The circulation of this flap would be more assured if one of the methods of delayed transfer were used rather than an immediate transfer.

and palmar flaps which may be either sutured end to end or side to side are often preferable for forming the commissure. If the skin of the fingers is lax and can be closed without tension, we suture it over the raw surfaces, but when there is tension, it is preferable to cover the raw surfaces with whole thickness skin grafts.

When the web is comparatively short and wide and does not extend further than the proximal phalangeal joint, we find the use of the Z incision with transposition of the flaps thus formed most helpful. In these cases, we make an incision along the rim of the web between the fingers and separate the web into two leaves. The arms of the Z are formed by incisions beginning at the ends of the primary incision; that on the dorsum extends from one end of the primary incision diagonally

across until it reaches approximately the level of the metacarpophalangeal joint between the bones; that from the other end extends diagonally on the palmar surface to a point opposite the lowest end of the dorsal incision. When the arms meet the primary incision, it is advisable to curve the incision so that the end of the flaps will be blunt rather than pointed. By undercutting the tissues outlined by these incisions two flaps are formed. These are raised and transposed, the tip of each flap being sutured into the extremity of the incision making the opposite arm of the Z, and the adjacent margins are sutured, thus releasing the web and forming a good working commissure.

When the fingers are closely fused, we proceed in either one of two ways, depending on conditions. In one group of cases, we form the commissure by means of two pedunculated flaps, one of which is raised on the dorsum of the fused fingers, with its base toward the wrist

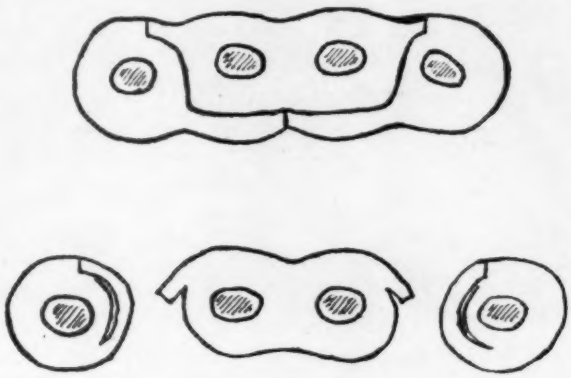

Fig. 33.—Stone's operation for syndactylism: This operation is devised to cover the index and little fingers in the cases in which there is fusion of all the fingers. A dorsal longitudinal incision is made along the full length of the web between the ring and middle fingers and transverse incisions are made on each side of this incision at the base and apex of the web, thus forming two quadrilateral flaps, the bases of which are on the index and little fingers. The index finger is separated from the middle finger, and the little finger is separated from the ring finger. The flaps are then brought around and will cover the defects completely. The raw surface on the dorsum of the middle and ring fingers is covered with a whole thickness graft or a pedunculated flap from a distant part.

about on the level of the metacarpophalangeal joint and the other on the palm on about the same level. Each flap should be sufficiently long to be able to pass between the separated fingers and be sutured without tension, the dorsal flap to the end of the palmar incision and the palmar flap to the end of the dorsal incision. The flaps should be blunt and as thick as possible in order to assure their blood supply. When the flaps touch as they lie adjacent to each other, the edges

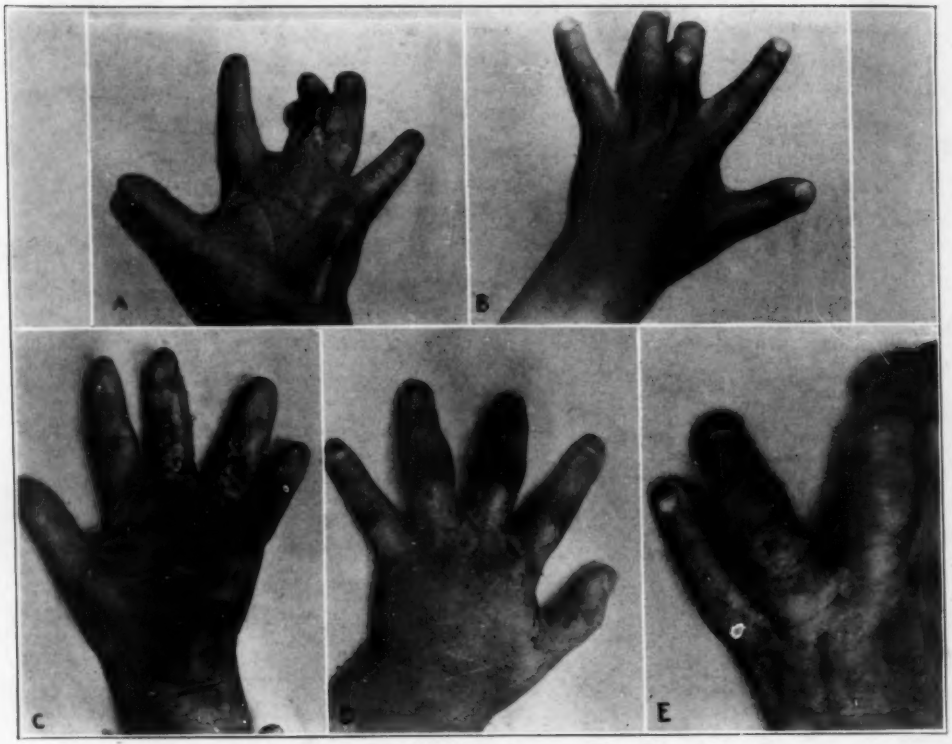

Fig. 34.—A white boy, aged 6 years, with no family history of syndactylism, showing the result of three previous operations performed elsewhere to relieve the defect. The first operation was done when the patient was 4 months old, and the others within the first eighteen months. This picture is not an uncommon one and illustrates our reason for not doing the complete operation at an early age. *A* and *B*, note the recurrent web extending beyond the proximal phalangeal joints, also the flexion of the fingers due to scar contracture. Scars outlining the flaps which were originally used to form the commissure can be seen at the base of the fingers. *C* and *D*, result three weeks after the secondary operation. The commissure was formed by blunt pointed anterior and posterior flaps which were drawn between the separated fingers and laid side by side. The tip of the palmar flap was sutured to the defect on the dorsum of the hand and the dorsal flap to that on the palmar surface. Where the edges of the flaps came in contact, they were sutured. The contracture of the fingers was then relieved as completely as possible by excision of scar and stretching. Then into the raw surface on each finger was sutured a measured whole thickness graft. A seasponge dressing was applied which was not disturbed for eighteen days. Note the depth and width of the commissure, also the grafts which have healed nicely. There is still slight flexion of both fingers, but it is probable that active use and massage will overcome this. *E*. Five weeks after operation.

are sutured. By this method a good commissure can be obtained, but at the sacrifice of a certain amount of the skin of both fingers, which in the closely fused cases, absolutely prevents closure of the edges of the skin by sutures and leaves a raw surface of varying size on the inner surfaces of both fingers. In order to cover these raw surfaces we use measured grafts of thin hairless whole thickness skin, usually obtained from the inner side of the arm, upper inner part of the thigh or prepuce, and sew these grafts into place with horsehair.

In another group of cases with very close fusion extending to the end of the fingers, we simply separate the fingers carefully along the normal line of division exactly in the midline and carry the separation back nearly to the level of the metacarpophangeal joints. This procedure leaves a raw surface on the inner side of both fingers extending to the bottom of the proposed commissure. The fingers are separated quite widely, and the outline of the defect is made with a piece of perforated cellosilk. This outline is transferred to the area from which the graft is to be taken, and a single whole thickness graft is cut and transferred to cover the raw surface and is sutured into place with horsehair. In this way a single measured whole thickness graft fills the defects on the sides of both fingers and also forms the commissure; in many instances, we consider this procedure the method of choice.

Method of Dressing.—We have found the following to be the most satisfactory dressing after the separation of the fingers and use it as a routine measure whether flaps or grafts, or both, have been employed in the reconstruction. The fingers fully extended are widely separated, and after a few layers of silver foil are applied, one thickness of gauze impregnated with 3 per cent xeroform ointment is placed evenly over the grafts or flaps. A strip of sterile moist seasponge is drawn down snugly over the newly formed commissure. Then the space above it between the fingers is packed quite tightly with pieces of seasponge until it is completely filled. Narrow pieces of sponge are inserted between adjacent fingers, and a large flat strip is placed on the front and another on the back of the hand, thus covering the fingers on all sides with the sponge. The whole is secured under even pressure by a bandage to fix the sponges and immobilize the fingers. An anterior hand and forearm splint is then applied. The tips of the fingers should be visible to check on the circulation. This dressing is left undisturbed for from two to three weeks, and when it is removed, the commissure is formed and the healing of grafts and suture lines is complete. Subsequently the sponge pressure may be reapplied if considered necessary, but ordinarily simple gauze will be sufficient until protecting dressings are unnecessary.

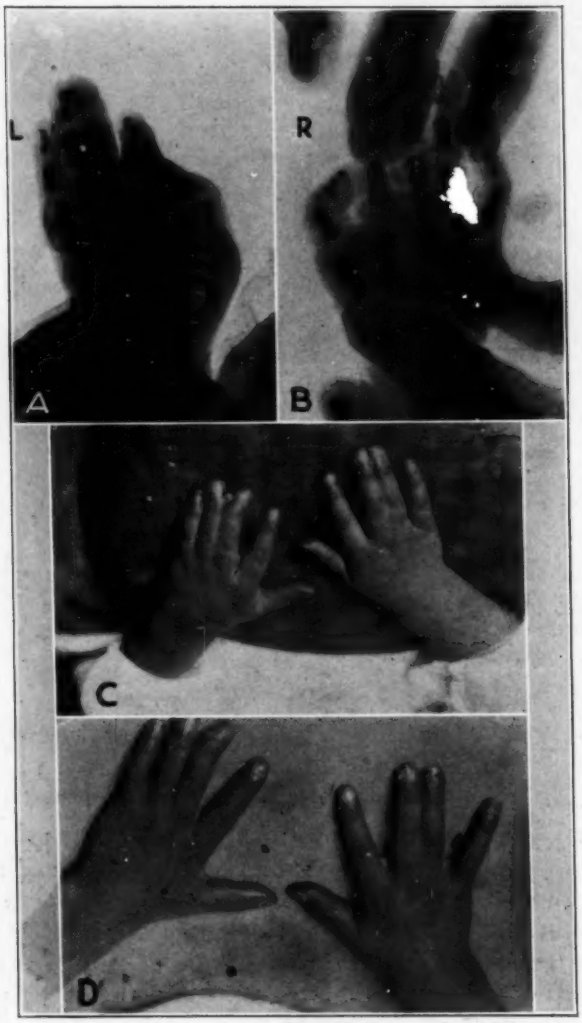

Fig 35.—A white boy, with a family history of syndactylism. The father, father's sister and paternal grandfather all had webbed toes; no webbing of the fingers was previously noted. There had been two other children born since this one who have had no sign of syndactylism. *A* and *B.*, x-ray plates taken when the patient was 1 day old. Note the shadow of the supernumerary finger on the proximal phalanx of the little finger of the right hand. There was also a smaller supernumerary finger attached to the terminal phalanx of the little finger of the left hand. Right hand: The third and fourth fingers were completely adherent to the tip but there was no fusion of the bone or nail. Left hand: There was fusion of the third, fourth and fifth fingers. There was fusion of the bone of the terminal phalanges of the third and fourth fingers, and the nails were also fused. The large phalangeal bones seen in the pictures are those of the nurse who held the hands. Toes: There was bilateral webbing of the second and third toes, nearly complete on the left foot. When the patient was 11 months old, the terminal phalanges of the third and fourth fingers of the left hand were separated. *C*, result of first operation. *D*, result of subsequent operations to prevent deformity and to allow normal growth. Note the separation of the fingers and that there has been no attempt to form wide commissures; also that the fingers have grown straight except the terminal phalanges of the third and fourth fingers of the left hand. In this case, there had been fusion of the bone and no lateral ligaments were present in the fused side, which would account for the tilting of the terminal phalanges.

TREATMENT FOR ACQUIRED SYNDACTYLISM

In the operative work for relief from congenital syndactylism, one usually deals with normal tissues. On the other hand, in acquired syndactylism, the tissues dealt with are either entirely scar or are scar infiltrated. Operative procedures that can be successfully carried out in the treatment for the congential cases cannot be done in the acquired cases, because the blood supply of the scar tissue is insufficient to nourish the necessary flaps. For this reason, the methods of treatment are somewhat limited. In a case of incomplete acquired syndactylism,

Fig. 36.—Types of acquired syndactylism: *A*, result of a burn. The fingers could not be flexed and there was little separation possible on account of the scar tissue. There is partial fusion between the second and third fingers and between the fourth and fifth fingers, but it is most marked between the third and fourth fingers where the commissure is obliterated and fusion is nearly complete up to the proximal phalangeal joint. Relief was obtained in this case by excision of the scar, followed by the use of a whole thickness skin graft which formed the commissure and covered all raw surfaces. A good functional result was obtained. *B*, result of a burn. The entire hand is covered with scar tissue. The fingers cannot be flexed or spread apart. Note the partial fusion of all the fingers and the obliteration of the web between the thumb and forefinger. Considerable improvement in function was obtained by shifting scar flaps and by the use of whole thickness grafts.

in which the web is fairly wide, it may be possible to relieve the condition by the use of the Z incision as described. The flaps should not be cut as long as when one is dealing with normal tissue, but they should be made as thick as possible in order to insure a better blood supply.

When the aforementioned procedure is impracticable on account of the type of fusion, the fingers should be carefully separated and the scar dissected out, if possible, down to normal tissue. Then into the defect thus formed a single measured whole thickness skin graft should be sutured with horsehair so that it covers the denuded surfaces of the fingers and forms the commissure.

Fig. 37.—Types of acquired syndactylism: *A*, result of severe burns. There is lateral scar contracture at the wrist which throws the hand out of line. The stumps of the proximal phalanges of all the fingers are covered with scar tissue and are closely fused. The web between the thumb and first finger is much shortened. In this case the first step was the relaxation of the contracture at the wrist after which the stumps of the fingers were separated and grafted, and the web between the thumb and forefinger was relaxed by a *Z* incision with the transfer of flaps. *B*, result of a severe burn. The proximal phalangeal stumps are covered by a thin painful scar and are completely fused. The length of the remaining phalangeal bones can be judged by comparing them with the length of the thumb. The stumps moved as one piece. The dimples in the scar are the openings of epithelial lined fistulas which run between the phalanges and are the remains of the original commissures. These have been drawn by scar contracture toward the end of the stump and are much displaced. The process of repair in this case was to remove the thin painful scar and replace it with a pedunculated flap from the abdominal wall which was arranged so that it covered the phalanges on both front and back. Later the finger stumps were separated and the commissures formed so that individual digital motion was possible, and in the end a fairly useful hand was developed.

In some instances in which the fingers are fused and in which there is little hope of securing a worth while functional result on account of the replacement of the integument by dense scar, it is advisable to dissect out the scar and cover the defect with a pedunculated flap. Depending on conditions, a gauntlet double pedicled flap, a tubed flap or some other delayed transfer type of flap may be used. After the flap has grown in place, the pedicle is divided and set in. Then in due time after shrinkage has taken place and the skin and subcutaneous tissues are completely adjusted to their new environment, the fingers may be separated, and the raw surfaces taken care of by one of the methods previously mentioned. The dorsal or the palmar surface or both may be thus covered with whole thickness skin with its subcutaneous tissue, and by this means a functionally useful hand may be developed from what was previously a painful claw.

TREATMENT FOR WEBBED TOES

It is seldom necessary to operate for relief from webbed toes, as this deformity, if incomplete, causes little if any disturbance of growth or function. However, if there is complete fusion of the terminal phalanges of toes of unequal length, such as the second and third, it is essential that these toes be separated sufficiently to allow unhindered individual growth. If this is not done early, the added deformity due to unequal growth will cause the longer toe to assume somewhat the position of a hammer toe, and in time considerable loss of function will follow; there will also be difficulty in getting a comfortable shoe. When such fusion exists, the terminal phalanges should be separated in the midline as soon as the unequal growth becomes evident, and the raw surfaces should be grafted with a whole thickness skin graft. This procedure is usually sufficient to control the situation, and we have never felt it necessary to separate the toes completely and attempt the formation of a new commissure on the normal level.

COMMENTS

As in any other plastic operation, tension must be avoided, and it is better to graft a raw surface than to attempt to suture edges of skin or flaps under tension. By the proper use of skin grafts, harmful tension may be absolutely eliminated. Primary healing is essential, as excessive scar formation may cause secondary deformity. We prefer grafts of whole thickness skin to any other type when dealing with raw surfaces in cases of syndactylism, as the ultimate results are much more satisfactory than when thin Ollier-Thiersch grafts or half thickness grafts are used. It is poor judgment to use the smaller types of grafts for covering raw surfaces in these cases, as the scar tissue subsequently formed will cause contracture.

In certain complicated cases, pedunculated flaps from distant parts may be used to supply skin for the commissure and also for closing raw surfaces. These flaps should ordinarily be prepared in advance by one of the methods of delayed transfer, although occasionally a gauntlet flap may be formed and used immediately. The operation of Didot, which looks so feasible in a diagram, and which is so frequently selected by the uninitiated, can seldom be utilized successfully when the fusion is close, as the skin is almost always too scant to allow the flaps to be sutured without considerable tension. It is possible that some of the cases of gangrene of the terminal phalanges that have been reported may be due to too much tension in the closing of these flaps rather than to an abnormal arrangement of the blood supply.

When several fingers are fused, it is advisable to separate only two of them on the same hand at one time, as the amount of skin available is usually scanty, and if more than two are done, the circulation of all may be jeopardized.

When closely fused fingers are separated, gangrene of the flaps and even of the terminal phalanges of one or both fingers occasionally occurs. Unless the underlying tissues are divided exactly in the midline, important vessels which normally adequately supply both fingers may be cut, and when the flaps are sutured, possibly under tension, the remaining blood supply is insufficient to nourish the part. Occasionally the blood supply of fused fingers is congenitally abnormal, and while it is sufficient to nourish both fingers when together, after separation takes place it may fail to take care of either one or both.

Fused phalangeal bones should be separated with a thin bladed osteotome, and the separation should be as even as possible in order to preserve the symmetry of the fingers. When chiseling is necessary, it is seldom if ever possible to make a skin closure by suture, so that skin must be grafted over the raw surface of the bone. There is often a tendency for the terminal phalanges that have been fused and separated, to tilt sometimes toward the normal side and sometimes toward the grafted or sutured side. The tilting of the terminal phalanx toward the normal side is probably caused by changes in the shape of the joint due to hindrance to proper development and to the weakness or lack of lateral joint ligaments. The scar contracture of the sutured or grafted side is often unable to overcome this tilting. The tilting toward the sutured or grafted side of finger can be easily accounted for by scar contracture, but in some cases hindered development and joint change are also present.

Massage and passive motion, with proper splinting, may overcome this tilting in time. If it cannot be corrected by these simple means and the deformity is objectionable, some operative procedure such as the excision of the contracted scar followed by grafting or the use of a

flap may be helpful. Should this be unsuccessful, osteotomy or the relaxation of the lateral joint ligaments may be indicated.

SUMMARY

Webbing of the fingers or toes either may be a congenital developmental defect or may be acquired. In the congenital type, there may or may not be a family history of similar malformations. The acquired type usually follows severe trauma or burns.

The fusion varies in degree from a slight lengthening of the normal web to complete coherence of the digits. Many operative procedures have been devised for the cure of syndactylism, but no single operation can be used successfully for all degrees of webbing.

In congenital cases, we have found that we can eliminate considerable deformity by the early separation of completely fused fingers of unequal length far enough back to allow unhindered individual digital growth; this is difficult to correct subsequently. The separation should be made as soon as the inequality of growth becomes apparent, however young the child may be, and skin should be grafted over the raw surfaces.

We have also found it advisable not to separate the fingers completely and reconstruct the new commissure until the child is at least 6 years old, as the work will have to be repeated in the majority of cases if it is done too early.

The key to final success in both the congenital and the acquired types of deformity is the formation of a satisfactory commissure, and this may best be accomplished by the use of either flaps or whole thickness grafts, depending on conditions.

The skin should be sutured over the raw surfaces left after separation of the fingers, if it is sufficiently lax to be closed without undue tension, otherwise a graft of whole thickness skin should be used. We feel that the use of whole thickness grafts for covering the raw surfaces and also for forming the commissure, is the method of choice in many instances, as by this procedure the problem of complicated flaps and undue tension can be avoided.

SURGICAL WOUNDS IN HUMAN BEINGS

A HISTOLOGIC STUDY OF HEALING WITH PRACTICAL APPLICATIONS: II. FIBROUS HEALING *

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Rational management of surgical wounds demands that the surgeon possess accurate knowledge of the processes of repair in tissues in human beings. The knowledge of healing of wounds in human beings is drawn largely by analogy from the observations of wounds in laboratory animals. Since the processes observed in wounds in human beings differ from those observed in tissues of animals, it is necessary to review the process of healing as found in the former.

In the first study, it was observed that there are two distinct types of healing processes, an epithelial and a fibrous process. Epithelial healing has been described. This paper deals with the fibrous type which is common to the dermis, fat, fascia and muscle. The observations and conclusions made are of direct clinical value.

STUDY OF CELLULAR MECHANICS IN FIBROUS HEALING

The material for this work consists of complete, transverse sections of surgical wounds in human beings, both clean and infected, in all stages of healing. Eighty-nine wounds, from one day to nine years old, were studied.

Both the literature and the histologic observations on the healing of wounds are practically interchangeable with the literature and observations on inflammation. In both processes, the most striking histologic picture is caused, not by fibroblasts, as they are ordinarily known, but by so-called exudate cells which appear in the tissues. Both processes result in terminal fibrosis. Many writers assign the function of phagocytosis of tissue débris to the exudate cells. Only a few suggest that the exudate cells help to form the newly deposited fibrous tissue. The origin, function and destination of the exudate cells form the basis and major part of the literature on the healing of wounds. These cells have many different names and descriptions. Clasmatocytes, macrophages, polyblasts, histiócytes and endothelial leukocytes are but a few of the names. I shall call them macrophages.

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There are three schools of opinion concerning the source of exudate cells. Perhaps the opinion most widely accepted in this country is that of Mallory and his co-workers, that macrophages are derived from the endothelium of the vascular tree and organs. A second opinion is that the exudate cells arise either by division or by "dedifferentiation" of tissue cells which become "embryonic fibroblasts." A third conception was inaugurated by Cohnheim, who believed that the exudate cells were leukocytes. Maximow [1] and his co-workers [2] have kept alive this idea, and they and other investigators by means of tissue cultures of adult lymphocytes and mononucleated leukocytes, have recently substantiated this view. There is no doubt now that lymphocytes, in vitro, will develop rapidly into typical macrophages, and even into typical fibroblasts which differ in no way from the macrophages and fibroblasts cultured from fibrous tissue.[3] Such cultures of blood cells recently have been observed to produce fibrous material resembling collagen in every respect.[4]

Although organic in nature, collagen fibers are apparently inanimate structures. No one has actually observed the formation of a collagen fiber in the body. Hence there are numerous opinions as to their method of formation, of which the three most important are: (1) that they are formed intracellularly by fibroblasts and cast out; (2) that they are formed in the ectoplasm of fibroblasts and cast off, and (3) that they are formed extracellularly. Whatever their source, from the surgical standpoint (the production of permanent tissue union) the fibers are the most important part of the process of healing. They provide for the union of severed tissues. They allow resumption of function in skin, fascia and muscle, and even in bone. They produce

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2. Bloom, William: Transformation of Lymphocytes of Thoracic Duct into Polyblasts (Macrophages) in Tissue Culture, Proc. Soc. Exper. Biol. & Med. **24**: 567, 1927. Carrel, Alexis: Growth-Promoting Function of Leucocytes, J. Exper. Med. **36**: 385, 1922.

3. Carrel, Alexis: Tissue Culture and Cell Physiology, Physiol. Rev. **4**: 1, 1924. Carrel, Alexis; and Ebeling, A. H.: Pure Cultures of Large Mononuclear Leucocytes, J. Exper. Med. **36**: 365, 1922. Foot, N. C.: The Endothelial Phagocyte: A Critical Review, Anat. Rec. **30**: 15, 1925. Maximoff, A.: De l'action stimulante de l'extrait de moelle osseuse sur la croissance et l'évolution des cellules dans les cultures de tissu lymphoïde, Compt. rend. Soc. de. biol. **80**: 225, 1917. Maximow, A.: The Cultivation of Connective Tissue of Adult Mammals in Vitro, Arch. Russ. d'anat., d'hist. et d'embryol. **1**: 105, 1916.

4. Ebeling, A. H., and Fischer, A.: Mixed Cultures of Pure Strains of Fibroblasts and Epithelial Cells, J. Exper. Med. **36**: 285, 1922. Maximow, Alexander: Development of Argyrophile and Collagenous Fibers in Tissue Cultures, Proc. Soc. Exper. Biol. & Med. **25**: 439, 1928.

the abnormalities of wounds. Whatever cells, if any, are required to produce them are subservient to them, and are primary only in the order of time.

Some writers have endowed the fibers of inflammatory or healing tissue with the ability to move independently and to direct their motion. In wounds in human beings the rapidity with which a mass of disarranged, newly formed fibers becomes alined and organized into a tissue might be regarded as substantiating evidence for such a conception. There is no evidence in wounds in human beings, however, that such powers exist in the collagen fibers of dermis or fascia.

It is commonly believed that fibroblasts produce the healing fibrous material only after the macrophages have cleared away tissue débris and thus have prepared the field for the cells present in the region to build new tissue. The succeeding observations of wounds in human beings show that: (1) there is no healing outgrowth of fibroblasts or fibers from the fascia or dermis; (2) the healing cicatrix is formed by the exudate cells, or the macrophages; (3) fat, instead of being a tissue inert in or inimical to the healing process, is of great importance in the furtherance of healing; (4) the determination of the healing fibrosis is directly related to physical forces, and (5) the blood lymphocyte apparently is the true healing cell, acting as both macrophage and fibroblast. All of these observations are of clinical significance.

Healing of the Dermis.—Throughout the study of the eighty-nine wounds in the series, certain features occurred frequently enough to justify general statements. The cut ends of the dermis remain inert. In wounds that are from one to thirty days old, regardless of the degree of healing, the cut margins of the dermis stand out as distinct lines. Nowhere is there evidence of any reaction of growth in the dermis itself. The resident tissue cells are not massed in greater than normal numbers near the margin of the wound; those that are present are not immoderately enlarged or dedifferentiated, and mitosis or other evidences of cellular proliferation are extremely uncommon. The exposed fibers do not change either in form or in number. The only definite reaction appearing in the dermis itself is a slight increase in the so-called round cell infiltration in the interstices about sweat glands and small vessels, yet the dermis is united rapidly by the formation of new fibrous tissue between its cut margins. Although in older wounds this interposed, uniting, fibrous tissue is intimately connected with the margins of the old dermis, in the earlier stages of its formation there is no arrangement of its cells or fibers to indicate its origin from the edges of the dermis. From these facts it must be concluded that the cells and fibers of the dermis do not take a part in the production of the healing cicatrix, and that the new scar tissue must therefore develop from cells not normally present in the dermis (fig. 1).

The new healing tissue between the edges of the dermis lies in the fat between, or immediately subjacent to, these edges. In wounds from four to thirty days old, this new tissue may be divided into three zones: (1) a cellular zone composed of macrophages; (2) an acellular zone of new fibers, and (3) a transitional or fibrocellular zone. These zones blend one with another. The cellular zone lies at the periphery of the cicatricial tissue and infiltrates the surrounding fat.

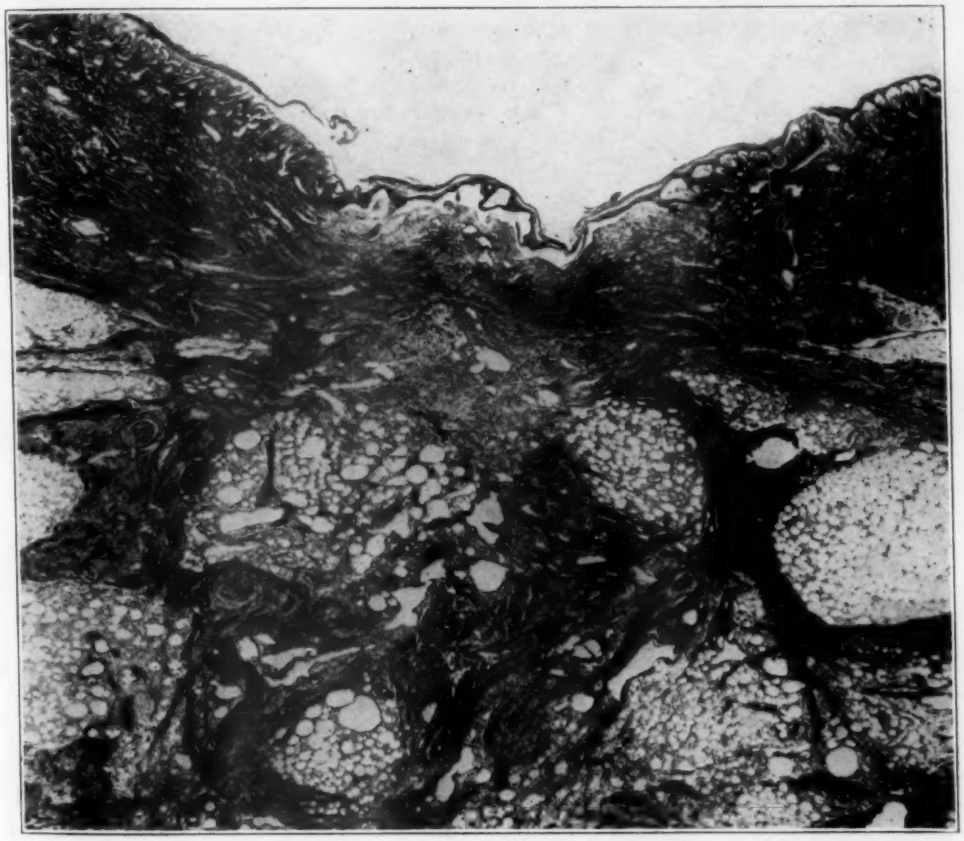

Fig. 1.—Dermal ends and fat in a wound four days old, in a human being. There are visible, distinct ends of old dermis, and new fibers between dermal ends. The relation of cellular infiltration to fat and the general direction of new fibers in new tissue between dermal ends are seen; × 18.

The fibrous zone lies more directly in the plane of the preformed dermis. The fibrocellular zone provides the transition between the cells and the fibrous material which is practically free of cells. The entire process takes place in the subcutaneous fat. There was not any evidence in any wound of the formation of new fibrous tissue without a cor-

responding macrophagic reaction in the surrounding fat. In a few wounds that did not show reaction in the fat, there was absolutely no evidence of fibrous healing. This is an important observation, for fat as a tissue is generally considered to contribute nothing to, or even to be inimical to, the process of fibrous tissue union (fig. 2).

In these wounds in human beings, new fibrous material is found much more intimately related to the normally nonresident exudate cells (macrophages) which infiltrate the fat than to the cells or fibers of the preformed, functioning, fibrous dermis. Since evidence is not found

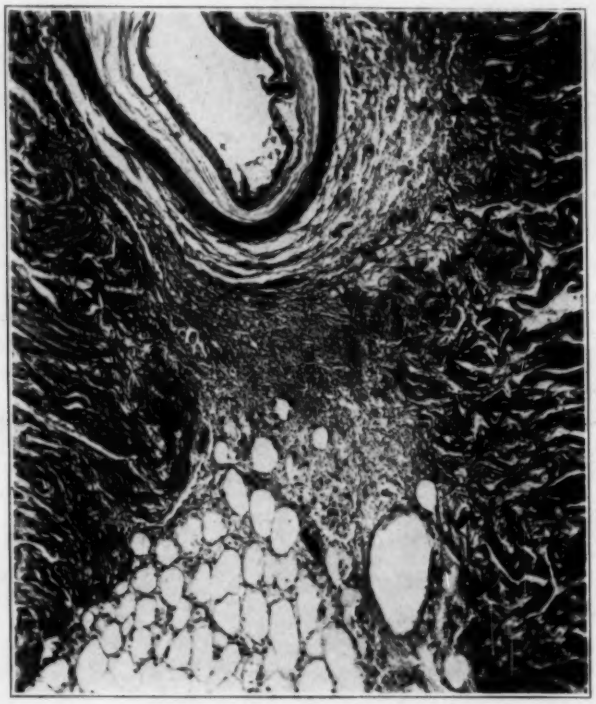

Fig. 2.—The healing of the dermis in a wound seventeen days old in a human being. There is no evidence of outgrowth of tissue from dermal ends. The cellular (macrophagic) zone in fat and the fibrocellular and fibrous zones, with direct transitions, are seen; × 75.

which points to increased activity of the normally resident fibroblasts, it must be concluded that, if the fibers are formed by cells, they are formed by the macrophages with which they are so intimately related. The three zones of the process, the cellular or macrophagic, the fibrocellular and the fibrous zones in a given wound, may therefore be considered as sequential stages of the process of production of fibers. As all three stages are found in any healing wound which is from

four to thirty days old, it must be concluded that the age of the wound alone does not determine the histologic picture of the wound.

Healing of the Fascia.—The same features are observed between healing fascial margins. The fascia does not present indication of rapid dedifferentiation, of multiplication, or of growth or movement of its cells or fibers into the wound from its cut margins. Scar tissue, however, forms between the severed fascial structures. Here again it must be concluded that the cells and fibers of the fascial structures do not take an active part in the formation of the healing cicatrix. As in the dermis, so in the fascia, the only visible reaction of healing is found in the fatty tissue interposed between the fascial margins or adjacent to them. Likewise, there are three zones of the healing tissue: the cellular zone, the fibrous zone and the transitional fibrocellular zone. Also, as in the dermis, the macrophagic zone infiltrates the fat, whereas the site of the most advanced fibrosis is in the fascial plane. Remnants of fat cells within the fibrocellular and fibrous zones, in both the planes of dermis and those of fascia, indicate that the entire healing process takes place in fat. To some extent, injured muscle may be the site of the healing process of fascia. When this happens, however, the muscle fibers atrophy and the stroma of the muscle takes on the appearance of fatty tissue. The macrophages then infiltrate the spaces in the stroma of the muscle which assumes the appearance of infiltrated fat. In much of the injured muscle there is gross and microscopic evidence either of a transition to fat or of a deposition of fat in the stroma (fig. 3).

The Organization of the Healing Fibers.—The earliest fibers of scar tissue are found in the transitional, fibrocellular zone of the healing process. Here the fibers are never very long, are often thin and wavy and do not show evidence of organization into bundles. They are not adherent one to the other, nor are their axes parallel. Such scar tissue is patently unable to function properly as a uniting substance capable of withstanding the stresses and strains put on dermis and fascia in daily life. To be a functioning tissue this new fibrous material must be organized. Evidence of organization is found in the fibrous zone of the process, where the cells have disappeared, and the fibers are agglutinated or clumped into heavier, straighter bundles, the axes of which are more or less parallel to each other and to the planes of the fascial structures in which they lie.

As has been noted, the most advanced transformation of the healing material into fibrous tissue lies always in the planes of the dermis and fascia. This observation is of great interest. Something other than the age of the wound and something related to such fascial planes must determine this mode of healing. The cut ends of the preformed structures do not determine it, for in the case of fascia they are more

often than not turned back from the line of the incision by the pull of the sutures so that they lie entirely out of the general fascial plane (fig. 4). The sole function of all fibrous tissue in the body is the bearing of stress and strain. Fascia and dermis are organized to bear linear forces in given planes. The suturing of fascia and dermis results in the maintenance of this function at and across the line of the incision. Naturally, stresses will be transmitted through the healing material in the general plane of the fascial structure. The occurrence of the most advanced stage of fibrous deposit and organization in the planes of the dermis and fascia, therefore, can be related to the functions of these

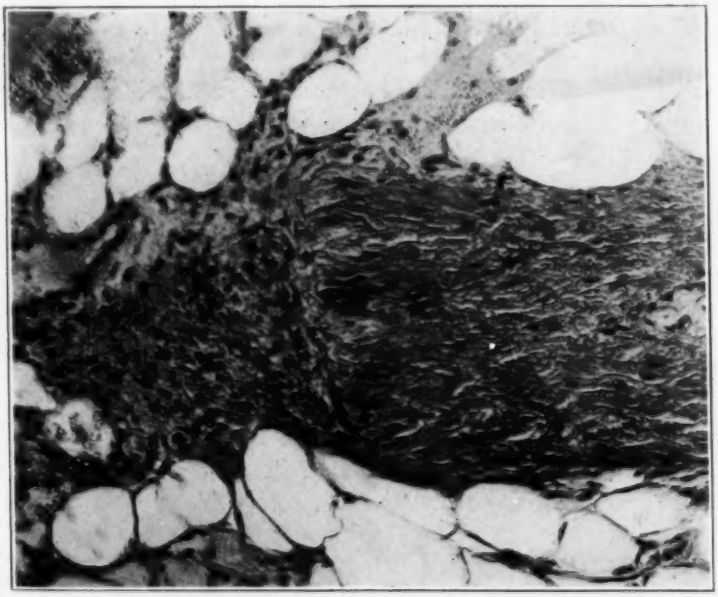

Fig. 3.—The healing of fascia in a wound eleven days old. There is no evidence of outgrowth of tissue from the fascial end. The cellular (macrophagic and lymphocytic) infiltration in fat at the fascial end and dilated capillaries bordering the infiltration are seen; × 170.

structures and to the transmission of linear stresses across the line of incision in the general planes of these structures.

The alinement of the fibers and their organization into a functioning tissue structure I consider to be the response of the new scar tissue to linear forces. The direction of the fibers of muscle tendons and aponeuroses throughout the body, and of the trabeculae in the bone, is but the normal expression of such a response. The disappearance of the healing cells fits directly into the mechanical economy of the process, for their presence would not add tensile strength to the new

tissue; on the other hand, it would tend to reduce tensile strength by separation of the bundles of fibers.

The principle of the alinement of fibers along the lines of physical forces is perhaps best illustrated in both normal and regenerating bone, in which, as is well known, the ultimate directions of the trabeculae are directly dependent on the directions of the lines of force exerted through the bone. In fact, the whole process of healing fibrosis may be compared to the repair of bone. The bone itself, the functioning structure, does not grow out from the fractured ends. The functioning structure, however, is quickly united by a deposit of scar tissue created by cells and fibers which formerly did not take a part in the normal supportive function of the bone. This fibrous mass is ossified and

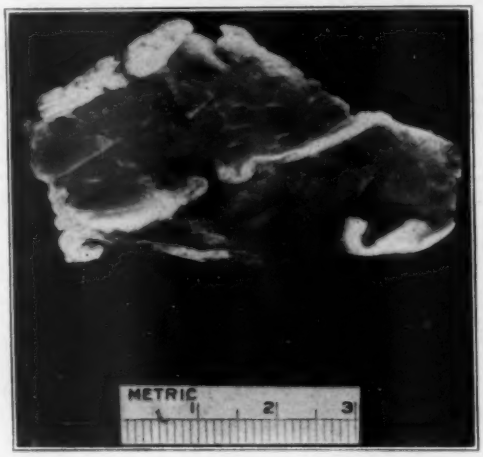

Fig. 4.—The block from which sections were cut from a wound ten days old, in a human being. Skin, fat, fascia, muscle and peritoneum are seen. The fascial ends are forced away from the line of incision by the tension of the sutures (actual size).

gradually reorganized according to principles mathematically and architecturally correct which relate to the sustaining of stress and strain. Fibrous healing is identical, except for the lack of ossification. Even this was present in two of the abdominal wounds studied, although the wounds were not related to any bone or cartilage. The comparison is still more marked in the light of Macklin's [5] work on the repair of bone, which, with recent observations on tissue culture, implicates macrophages as the source of the primary fibrous callus in the repair of bone.

5. Macklin, C. C.: The Development and Function of Macrophages in the Repair of Experimental Bone-Wounds in Rats Vitally Stained with Trypan-Blue, Carnegie Institute, Contributions to Embryology **9**: 3, 1920.

In the reorganization of ossified material, certain cells appear to destroy or to build bone according to lines of force that can be projected through the substance. The alinement of the resulting trabeculae is therefore dependent on the activities of cells. It is possible that fibroblasts or macrophages may, by a response to linear forces projected through new scar tissue, move through it in such a manner that they agglutinate and aline the fibers in the direction of the stresses which

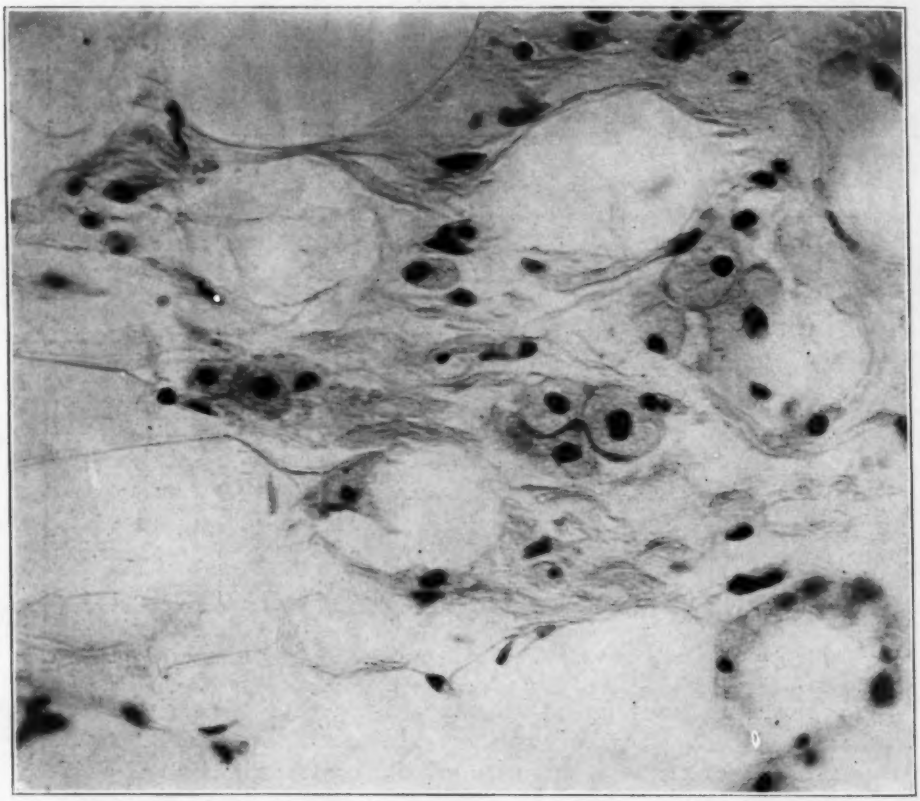

Fig. 5.—Fibers and macrophages in fat of a wound, ten days old, in a human being. The relation of new fibers to macrophages is evident. Lymphocytes, macrophages and intermediate forms are present; × 450.

the new tissue bears. The remarkable disappearance of the fiber-forming cells concomitant with the appearance and organization of new fibrous tissue, however, cannot be assigned completely to an emigration of the cells.

The Origin of the Healing Fibrosis.—Low-power microscopic fields show the apparent transition of masses of macrophages into organized connective tissue containing few cells. High-power fields reveal the

direct transition of both intracellular and extracellular cytoplasm of macrophages into fibers (figs. 5 and 6). In some cases this transition appears to be the result of a streaming out of the cytoplasm behind a moving cell. As the macrophages appear to form the new fibers, and as the cells normally resident in the connective tissue appear to take no part in the production of the healing tissue, one may well question: What is a fibroblast? In wounds in human beings it is evident that the macrophage is the true fibroblast. New fibers are

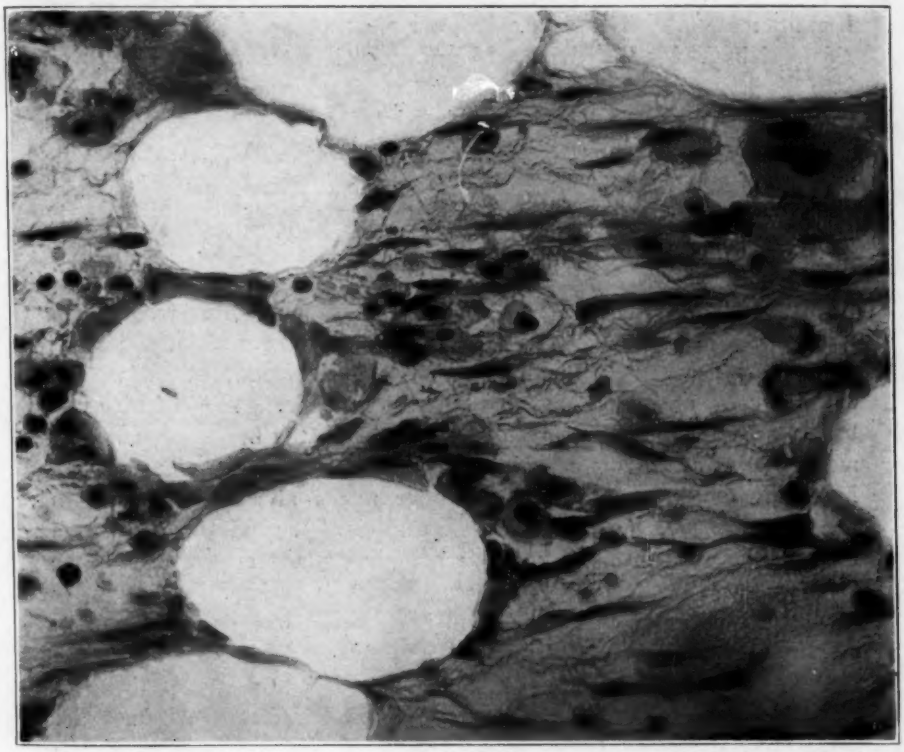

Fig. 6.—Fibers and macrophages in fat of a wound ten days old, in a human being. Some fibers are related to cellular cytoplasm; other fibers are not related to any cells or cytoplasm. Fat has been replaced by cells and fibers. Transitional forms between lymphocytes, on the one hand, and macrophages and fibroblasts, on the other hand, are seen; × 450.

found chiefly among macrophages, and masses of macrophages are replaced by practically acellular fibrous tissue. Definite indication of the disintegration of the macrophages is concomitant with the appearance of a large number of fibers among them. New fibers are found as part of the strung-out cytoplasm of macrophages, as partially intracellular and partially extracellular fibrils, and as totally extracellular

objects formed from some material present in the intercellular spaces. Occasionally new fibers of collagen may be traced directly into fibers of fibrin. Certain it is that as fibrosis progresses the cells disappear, chiefly by disintegration. A few of the macrophages appear to take on the cytologic characteristics of ordinary tissue fibroblasts. From these observations it appears that the determination of new fibrous tissue is dependent on two factors: (1) the presence of a chemical substance in the healing zone which can be changed quickly into collagen fibers, and (2) the passage of physical forces through the healing material. The macrophages appear to provide the necessary chemical basis for the fibers. The material is set free for coagulation into fibrils, and the field is freed for the most economical organization of the fibrils by means of the rapid disintegration of the macrophages.

The Origin of the Macrophages or Wound Fibroblasts.—In these wounds in human beings it is obvious that macrophages are not derived from the fibroblasts normally present in the preformed tissue. If they are endothelial cells, as many believe them to be, they are unlike true endothelial cells which line the vessels of the region. Their residence is fat. Normally, in fat there are no cell forms from which such a large number of cells might spring in such a short time, and there are but rarely any evidences of the multiplication of cells. The exudate cells, or macrophages, must be derived from cells which come to the region of the wound from elsewhere in the body. Among the macrophages are many cells identical with lymphocytes of the blood. Many of the larger macrophages have nuclei almost identical with the small, compact nuclei of lymphocytes (fig. 7). Indeed, transitional forms between lymphocytes and macrophages are everywhere to be found. Lymphocytes are found abundantly as perivascular infiltrates about dilated veins and capillaries and within the vessels of the region in numbers greater than normal. The lymphocyte is known to be a motile cell, and to be capable of rapid growth into macrophagic form in vitro. It may be concluded, then, that the lymphocyte of the blood is the cell which originally infiltrates the fat of the region of the wound, and that the macrophage is derived from the lymphocyte by a process of growth. Thus the lymphocyte becomes the real fibroblast in healing of the wound. Such a fibroblastic rôle for the lymphocyte has long been accepted by the French because of the constant occurrence of lymphocytes in chronic inflammatory connective tissue.

The Rôle of Fat in the Process of Healing.—Fat is the place where the healing process occurs, and lymphocytes are the primary infiltrating cells, which by their growth become macrophages. The infiltrating cells do not merely push aside the fat cells as they enlarge to become macrophages. The fat cells are replaced by the growing cells, which take on a greatly swollen and foamy appearance as the fat cells diminish

in size. Fat stains show that the infiltrating cells are packed with fat. It must be concluded, then, that the growth of the infiltrating lymphocytes is due directly to the ingestion of the fat in which they lie.

The histologic picture of macrophages in fat has been described by many authorities as indicative of a development of new fat cells; the macrophages are assumed to be young fat cells with their content of fat still in droplet form. In wounds in human beings, however, such a picture is the exact opposite of that of the generation of fat.

Fig. 7.—Fat with typical infiltration of macrophages and lymphocytes in a wound seven days old, in a human being. Lymphocytes, macrophages and all intermediate transitional stages are present. There is replacement of fat cells by the infiltrate; × 120.

It is the picture of replacement of fat. This interpretation is completely substantiated by the histologic picture of progressive lipodystrophy, in which disease the subcutaneous fat is completely replaced by sclerotic fibrous tissue; the histologic phases of the process are absolutely interchangeable with those found in wounds of human beings.

It already has been noted that the healing fibrosis takes place in fat; now it appears that fat is the food for the healing cells. These

conclusions are at direct variance with the clinical impression that subcutaneous fat, as a tissue, serves only as unavoidable débris in surgical incisions. Since the final fibrous material is largely deposited by the disintegration of the healing cells, and since the healing cells live chiefly on fat, it may be further concluded that the subcutaneous fat serves as the chemical basis for the healing fibers. Adipose tissue, therefore, serves as an emergency food depot for healing cells. Such a conclusion is substantiated by the fact that fat is the food of the cells of the embryo; Maximow [6] and Carrel [7] have shown that lymphocytes act as embryonic cells. Such a conception of fat as a food depot for emergency repair of tissue suggests an explanation for the widespread distribution of fat in the body, particularly along fibrous structures subject to trauma, such as the skin and fascial sheaths. Fatty tissue is not present within the central nervous system, where true fibrous tissue does not form after injury.

The Healing of Fat as a Tissue.—The healing process which unites fascia and dermis takes place in fat. In the healing of fat itself, the infiltrating cells are scattered along the line of incision, extending laterally between fat cells and fat lobules or invading the fat cells themselves. Their growth into macrophages and the deposit of fibers by their disintegration are as described for fibrous structures. The chief site of new fibrous tissue in fat is along the small fibrous trabeculae which course through the fat; this fact again impresses one with the relation between healing fibrosis and structures that transmit tension. In old, long healed wounds, no evidence of healing fibrosis may be found in the fat, indicating that absorption follows the process of fibrosis when it takes place in regions the function of which is not to bear permanent stress.

Healing of Muscle.—Muscle is healed by an increase of macrophages at the injured area. The muscle fibers atrophy or retract from their connective tissue stroma. The stroma becomes packed with lymphocytes, macrophages and intermediate forms, all of which disappear as fibrosis occurs. The fibrous deposit unites the stroma of the muscle on one side of the incision to that on the other side, thus assuring maintenance of the function of the muscles at the part. As the healing process is continuous throughout the wound, it is not surprising that structures such as skin and muscle, or fascia and muscle, which normally are separated, may become adherent (fig. 8).

Healing of the Peritoneum.—The healing of the fibrous portion of the peritoneum is included in the description of fascial healing. No true, serosal, lining cell layer was observed in any of the wounds

6. Maximow (footnote 3, fifth reference).
7. Carrel (footnote 2, second reference).

examined. It may have been lost in the process of preparing the tissues. Any conception of the action of such cells is not permissible from this study.

Healing by Primary and Secondary Intention.—The observations given apply alike to "clean" and to infected wounds. Any single wound may be partly clean and partly infected. In wounds of human

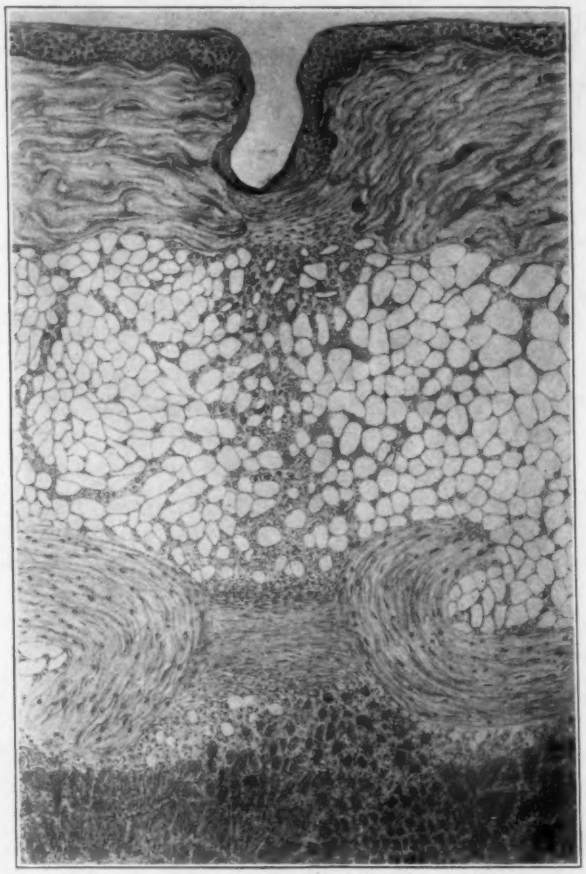

Fig. 8.—Diagrammatic drawing of a wound ten days old. Epithelium dips into the wound over inert dermal ends. Both dermal and fascial ends do not show increase in or outgrowth of cells. There are three zones of healing in the same wound, fibrous in planes of fascia and dermis, cellular in fat, and fibrocellular between these zones. Macrophages have infiltrated the muscle, and macrophages and fibers have replaced fat. There is no granulation tissue. The dermis has healed across the lowest part of the dermal incision.

beings, granulation tissue is seldom found, even though there is evidence of infection in the field. When present, it is always on a surface,

either superficially, as in a sinus, or lining a space deep in the tissues. Even in typical granulation tissue, the types of cells present substantiate the conception that the lymphocyte and macrophage are the healing cells. Granulation tissue must be regarded as a vascular overgrowth into an open space, by means of which the healing cells are brought into the space and, in the absence of fat, supplied with nourishment from the blood until they are present in sufficient numbers and have developed sufficiently to produce the fibrous material which will not only obliterate the cavity but which will produce a stress-resistant tissue in the space. It is merely a vascular phase of the fundamental type of healing process and is related to infection only because it is in infected wounds that spaces within the tissues most frequently develop, and because surface wounds are invariably contaminated. Primary and secondary intention, therefore, represent but two phases of one fundamental healing process, and healing is primarily the same in both clean and infected wounds.

Wound "Débris" and the "Latent Period" of Healing.—The idea that macrophages do more than simply act as scavengers of "tissue débris" is one not generally accepted. In fact, the term débris has been applied to the normal exudative products of inflammation and to normal fat, as well as to injured or useless tissue. In wounds in human beings, degenerated tissue is not found in an amount sufficient to account for the number of macrophages that appear. It is suggested by this fact, and by the part played by the "scavenger" macrophage cells in producing fibrous deposit, that the term débris is improperly used in this connection. It appears that the exudative products in the healing of wounds, and what injured tissue there may be, possess a direct contributory function in the healing process as food for the healing cells and then as constituents of the fibers which are deposited. In other words, healing begins at once, and there is no period of degeneration, or of dedifferentiation preceding the period of regeneration.

The Process of Healing of Wounds as Related to Function of Severed Tissues.—Since Virchow and the discovery of mitosis, the tendency has been to consider it but logical that new tissue must be derived directly from old tissue of the same kind. The rapid derivation of new tissue from dermis or fascia, however, would create great changes in those tissues through cellular proliferation and movements or by so-called dedifferentiation of the tissue. Such changes would tend to separate the fibers and thereby to weaken the tissue and jeopardize the normal function of the structure. If that function is ever important, it must be more so when the continuity of the part has been destroyed by surgical incision. Furthermore, in surgical wounds,

an added function falls on the immediate ends of the severed fibrous structures. On them falls the strain transmitted by the sutures when the wound is closed. Increased cellularity of such fascial ends, with resultant swelling of the fascia and consequent separation of the fibers, would make the suturing of fascia or dermis a procedure of doubtful value, for sutures would tear out easily. Fascial suturing is, however, the main source of strength in the closure of wounds. To make this true, the strength of the fascia in wounds of human beings is maintained by minimal changes from the normal structure of the tissue.

Considering the necessity for the maintenance of normal function of the preformed tissues, it does not seem illogical, in spite of the belief inaugurated by Virchow, that new connective tissue should be derived in some manner not necessitating changes in structure of local tissues. When the economy of the organism is considered, the inauguration of healing fibrosis through the medium of infiltrating lymphocytes, the growth of the lymphocytes by the ingestion of the local, nonsupportive fat and the deposit of the uniting fibrous material between the margins of the supporting tissues by the lymphocytes seems a logical process.

The implication of lymphocytes in the deposit of fibrous tissue suggests that, in cases in which the healing of wounds has been delayed without apparent cause, some method may be found by which the fibroblastic potentialities of the lymphocytes of the blood may be stimulated.

Controls.—As controls for this work, 101 experimental surgical incisions in animals were studied. As in the wounds in human beings, the cells and fibers of fascia and dermis do not show evidences of proliferations or movement into the wound. From this point on, the observations in the animals do not correspond with those in the human material. In the guinea-pig, rabbit and dog, granulation tissue is responsible for by far the most common picture of healing, even in apparently clean wounds. In swine, as in human beings, granulation tissue is rarely seen. This difference is accounted for by the character of the subcutaneous tissues in the various subjects. In the smaller animals, the subdermic tissue is largely areolar tissue; this is a potential space which, if edema is present, becomes filled with fluid. In swine and in human beings this space is occupied by compact adipose tissue which can be directly ingested by macrophages; hence, granulation tissue is not formed.

In animals, the origin of the healing cells is not clear. Mitosis is common, which suggests that the healing cells are of local origin. The form of these cells also more nearly resembles that of swollen tissue fibroblasts. Nevertheless, transition forms from lymphocytes

to small macrophages and fibroblasts also are present, and the larger cells contain many fat-staining globules. Masses of macrophages, such as occur universally in wounds of human beings, do not appear in the animal tissues. Here is a distinct difference between the histologic picture of healing in animals as compared to healing in human beings. This difference emphasizes the fact that the conception of healing in surgical wounds of human beings must be built up from observations on human tissues.

CLINICAL APPLICATIONS

The concept of healing in wounds that has been explained in the foregoing paragraphs finds direct application to several well established clinical facts and surgical procedures, and throws doubt on some clinical impressions.

Fat in Surgery.—There is a paradox in the attitude of surgeons toward fat as a tissue. They distrust subcutaneous fat because of its poor ability to resist trauma and its tendency to become infected and to interfere with the healing of wounds. At the same time, surgeons, as a routine measure, sew omental fat over intestinal suture lines to support them, and to aid healing, in spite of the fact that such places present the greatest possible likelihood of contamination, and fat the least possible supportive strength. There is no demonstrable difference, histologically, between the two types of fat, and Mann [8] has shown experimentally that subcutaneous fat may be substituted for omental fat in technical procedures with as good results as though omental fat were used.

The observations presented in this paper show definitely that subcutaneous fat serves as the place in which the healing process occurs and as the source of nourishment for the cells that take part in it. On this twofold function of fat is based the healing of parietal incisions. Therein also must lie the value of fat of any sort when placed about intestinal suture lines.

The common opinion that subcutaneous fat acts as a deterrent to proper healing must be explained on some basis other than that the fat tissue itself is the deterrent.

An Explanation of the Broad Scar of a "Knife-line" Incision.—It is common knowledge that, after ordinary over-and-over suturing, an epithelial scar, which ten days after the incision is well healed and of the "knife-line" type, may be a broad and irregular scar ten months later. On the other hand, the wound that is closed with closely placed mattress sutures so as to evert both margins of the skin may not look

8. Mann, F. C.: The Transplantation of Fat in the Peritoneal Cavity, S. Clin. North America **1**:1465, 1921.

well before the stitches are removed, yet may be barely visible after ten months. The studies reported here show that the healing of skin occurs through the interposed or subjacent fatty tissue. On transverse section, the incision in the skin is found to be a deep crevice in the dermis, the bottom of which is formed by new fibrous tissue in the fat. The parts of the dermal margins that protrude above the bottom of the crevice will be lost to the function of the dermis, as the lines of force exerted across the line of incision through the general plane of the skin, will pass beneath them. Gradually, then, these upright dermal margins disappear, either by being retracted laterally into the general plane of function, or by being absorbed. In either case, there is flattening out and exposure of the rather extensive scar epithelium which had dipped into the depths of the dermal wound, and rearrangement of the epithelium about the incision line, which results in the ultimate scar on the surface being a wide scar instead of a narrow line.

In wounds closed with everted edges, the interdermic scar tissue is also formed with the help of the fat. In this case the fat unites the approximated under surfaces of the dermal margins for some distance back from the actual dermal edges, with a short length of new fibrous matter between the under surfaces. When the sutures are removed, the tension in the surrounding skin tends to pull the everted edges back into the general dermal plane. The tension is transmitted through the interposed scar, which acts as a fulcrum for the everted dermal ends; the result is that as the ends drop back into the dermal plane they are constantly forced toward each other. In this way any resorption of preformed dermis that may take place will not extend very far to either side of the incision. The end-result is, according to both gross and microscopic appearance, a very narrow "knife-line" scar.

Fat and the Mechanics of Closure of Wounds as Related to the Causes of Postoperative Hernia.—By the described relation of physical forces to the formation and organization of fibrous tissue, the value of sutures may be explained on a basis which will permit a working explanation of the cause of postoperative hernia.

Sutures serve to unite severed fibrous structures so that they can continue their normal functions. This fact alone requires that the function of the fascia must be maintained by the sutures at and across the line of the incision during the healing of wounds. Sutures that fail, or that are formed or placed so that the stresses in the fascia or dermis cannot pass across the wound in a normal manner, will be the cause of abnormal healing.

From the observations presented, it may be assumed that the beginning of a postoperative hernia occurs in a place where the continuity

of fibrous, parietal structures is broken or weakened. To cause this condition, sutures must have failed or must have been so placed that the functional stresses of the part are not evenly distributed across the entire wound. As a result, at that point in the closure where the normal fascial function is diminished, the intra-abdominal forces exerted perpendicular to the parietal plane will exceed the tension existing in the healing tissue between the fascial margins. This may be represented diagrammatically, the length of the smaller lines representing the stresses transmitted to the fascia and across the fascial incision, by the sutures.

At point *A* of figure 9, due to faulty spacing of the sutures, tension does not pass across the line of the wound in the fascial plane. This fact permits forces *B-A*, which are exerted by intra-abdominal pressure and which are at right angles to the fascial plane to cause separation of the tissues. Such forces are found in the intra-abdominal tension. If, by faulty suturing, the area above *C-D* is puckered or relaxed

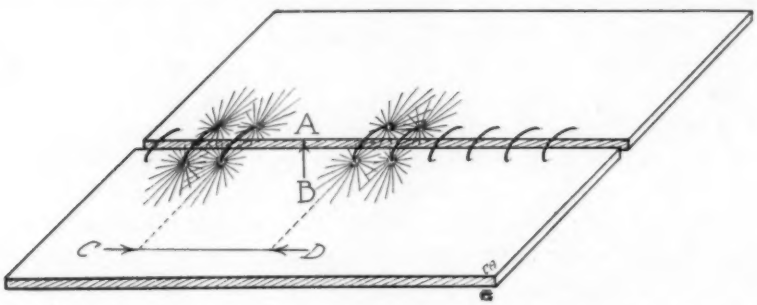

Fig. 9.—Diagram of physical factors determining the healing of fascia and the formation of postoperative hernia.

parallel to the incision, this will further tend to weaken the point *A* and permit greater penetration of abdominal organs into the wound. The omentum or another organ becomes interposed between the surfaces of the wound through the action of the intra-abdominal pressure on it. If there is sufficient parietal tension against the walls of this organic plug, there will be adhesion of fascia to organ, providing the organ is in one position long enough to permit a fibrous union to take place, and providing both wound cavity and organ are not covered with serosal cells. If fascia at *A* is slack because of a force, *C-D*, then stress will not be transmitted at *A* and firm adhesion will not form although the penetrating organ may be stationary. The surface of the pocket in the wound is transformed by macrophages into a thin fibrous membrane which becomes a thinned out and expansible continuation of the fascial margins of the wound and forms the fibrous coat of the resulting postoperative hernia. If this fascial extension is not adherent to the penetrating viscus, it becomes covered with

serosal peritoneal cells. The prevention of postoperative hernia depends, therefore, largely on the proper mechanics of the fascial closure.

The objection will be made that, if, histologically, fat between fascia is an aid to healing, why is it that, clinically, it is a well established practice to exclude omental tags and lumps of subcutaneous fat from between fascial margins when wounds are sutured in order to prevent postoperative hernia? The answer is found in figure 9. It is corroborated by the well known tendency of the omentum to form fibrous adhesions; the fat itself is not inimical to healing fibrosis. Lumps of fat are removed from the suture line at the time of closing simply because of the difficulty of assuring proper spread of tension across the entire line of incision if any interposed mass is present between the fascial margins. The removal of the physical mass, therefore, is the chief desideratum in this surgical practice. The properties of fat, however, make it particularly advisable to remove masses of it from the field through which tension is transmitted. It is of such a consistence that it may change its shape and slide out from between the fascial margins, or become liquefied and dispersed, leaving, if the healing tissue has become fairly firm, an accentuation of the condition at *A* in the diagram; a small piece of moving viscus may insinuate itself in the space that is formed. A further confirmation of the fact that it is the mass which the fat represents, and not the fat itself, which must be removed from the line of fascial closure is found in the practice of overlapping fascial membranes from which it is impossible to remove all the fat. Healing in such cases takes place quickly and permanently. Full-thickness skin grafts also prove, clinically, that fat as a tissue is not a hindrance to healing, and they illustrate the importance of pressure or tension in the production of fibrous tissue.

The Closure of Wounds in Layers.—There is no doubt that the closing of wounds according to their anatomic layers procures excellent results. From this work, the explanation of the benefits of this procedure is found in the resulting maintenance of the functional planes of the fibrous structures. An explanation more commonly given is that by sewing fascia to fascia the cut ends are approximated, whereby the outgrowth of fibroblasts from them is minimal and direct, and that healing is thereby accelerated. In wounds of human beings, however, there is no histologic evidence that the cut ends play any part in the production of healing. Indeed, the fascial ends are not only inert, but they actually are turned away from each other by the pull of the sutures, as is readily observable during the closing of any fascial layer at operation. Fibrous healing is the result of a "fill" of new fibrous tissue between the severed structures, and not the product of any healing outgrowth from these structures.

CONCLUSIONS

1. Fascia and dermis do not take any active part in the healing of surgical wounds in human beings.

2. Fat is the site and the basis of the production of new fibrous material in wounds of human beings.

3. Macrophages are the true fibroblasts of wounds in human beings.

4. New fibrous scar tissue is formed at the expense of the cells which produce it.

5. Given the proper chemical material in the healing zone, the physical forces in that zone determine the rate of deposit of fibrous material and the organization of the fibers into a functioning tissue.

6. Macrophages are derived from lymphocytes of the blood which develop rapidly by the ingestion of fat.

7. The fundamental healing process is the same in both clean and infected wounds.

8. The histologic picture of fibrous healing in human beings is different from that in animals.

9. The mechanics of closure of wounds determine the appearance of the scar on the surface and the occurrence of postoperative hernia.

SECONDARY OR LATE PERFORATION OF SMALL INTESTINE FROM TRAUMA *

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Not infrequently the surgeon is called on to take care of the patient with abdominal injury caused by blunt force. Commensurate with its importance, this subject has been given much study, and there are many excellent articles dealing not only with certain phases of the subject, such as rupture of the spleen or liver, but also taking up the question of abdominal trauma as as whole. Demel [1] has recently presented such a review. In these various contributions much is said about primary rupture or perforation of the intestinal tract, but little is to be found concerning perforations that occur later when the patient is considered out of danger. I shall report two personal cases of such late perforation, supplementing them by illustrative cases from the literature, and from these data I shall endeavor to give a more or less comprehensive discussion of the condition.

REPORT OF AUTHOR'S CASES

CASE 1.—A farmer, aged 33, was admitted to the W. S. Major Hospital on May 22, 1926, at 2 a. m., with a diagnosis of intestinal obstruction. He had become ill suddenly about midnight two days before, when he was awakened by severe pain across the midportion of the abdomen. He drove several miles to a physician's office, vomiting before arrival; two hypodermic injections of morphine were necessary to obtain relief. The next day the pain and the vomiting persisted. He had not had a bowel movement since the morning before the onset of the illness, cathartics being vomited, and an enema was unsuccessful. He had had no fever. For a year preceding, there had been an indefinite abdominal complaint at intervals as if he were going to have diarrhea. He had, however, had no treatment and no operations. Though poorly nourished, he did not appear seriously ill. Results of the physical examination were normal, with the exception of the condition of the abdomen. There was moderate tenderness just to the right of the umbilicus, but no definite rigidity and no distention; the left lower quadrant was flat to percussion. The blood pressure was 128 systolic and 78 diastolic; temperature, 98.8 F.; pulse rate, 90; respiratory rate, 20. The urine was normal; the leukocyte count, 15,600.

Exploratory celiotomy through a right paramedian incision was performed at 10 a. m., on May 22, with the patient under ether anesthesia. The peritoneal cavity contained about 200 cc. of free serous fluid, most abundant in the right upper quadrant. A portion of the small intestine, at the level of the junction of jejunum and ileum presented; for about 10 inches (25.4 cm.) it was dilated, red and con-

* Submitted for publication, Jan. 25, 1930.

1. Demel, Rudolf: Ueber die Anzeigestellung zum operativen Eingriff bei stumpfen Bauchverletzungen, Arch. f. klin. Chir. **135**:542, 1925.

gested, with its peritoneal surface slightly glazed. It had the appearance of a loop of intestine strangulated for a short time in a hernial sac. Search of the entire abdomen revealed nothing further. The circulation of the portion of intestine involved appeared intact and the intestine viable. It was therefore replaced and the abdomen closed without drainage. The cause of the intestinal pathologic process was obscure, and no diagnosis was made.

Postoperative Course.—The temperature rose to 101 F. on the second day, but promptly returned to normal and remained so. The pulse rate never exceeded 100 and stayed around 80 most of the time. An enema secured good results. Three days after food was again given to the patient, he vomited. The abdomen became markedly distended and tympanitic, relief being obtained by enemas. He began to pass large fluid stools frequently, six the fifth day, nine the sixth, six the seventh and five the eighth day. There was no gross blood. He was given a liquid diet from the third to the sixth day and a soft diet after that. On the ninth day he complained of pain in the abdomen, not localized, and of severe pain in the lumbar region. The abdomen became markedly distended and tympanitic, but there was no vomiting. The patient was relieved by the use of morphine. He had a good night's rest, and the next morning the distention had disappeared. There was a good bowel movement, and he felt quite well. The next day he was out of bed in a wheel chair and had no further complaint; he had two or three large formed stools a day, and was discharged apparently in good condition fifteen days after the onset of his illness. At no time following his operation did he show any particular abdominal tenderness.

Nothing further was heard concerning him for two days, when he was readmitted to the hospital on June 6 at 2 p. m. He stated that he had scarcely left after eating his noon meal, when he began to have abdominal pain. On arrival at home, the pain became exceedingly severe and he vomited. He called his physician twice during the night in order to receive morphine. Pain and vomiting continued all the next day, and there was no bowel movement. Cathartics and enemas were taken without avail. He steadily became worse, and returned to the hospital. He was in a state of collapse with profuse sweating. The temperature was 97.2 F.; pulse rate, 106; respiratory rate, 36. His abdomen was markedly distended and tense, though he complained little of tenderness on pressure. He was clear mentally. His temperature rapidly rose to 101 F., then to 102 F.; the pulse rate rose to 140 and the respiratory rate to 50. He vomited fecal matter, and died at 4 a. m. on June 7, seventeen days after becoming ill.

At the time of his second entrance to the hospital, the following additional history was obtained. During the morning previous to the onset of his illness, while plowing, his plow-share struck a large rock and was thrown out of the furrow, and he was struck a brisk blow in the abdomen by the handle. He felt a little faint, but soon recovered and paid no further attention to it. He never mentioned the occurrence to either his family or his physician, thinking it insignificant and of no relationship to his illness. Also, just previous to leaving the hospital on June 4, he had gorged himself on a large amount of fresh strawberries which were smuggled into the institution by a relative.

At necropsy, gas escaped when the peritoneum was incised. The entire upper part of the abdomen from the level of the umbilicus to the area over the right lobe of the liver contained fecal material. The intestines of the upper and mid-portions of the abdomen were plastered together, the loops distended. The right flank was closed off by plastic adhesions, serous fluid being encountered when these were broken up. A large amount of dirty appearing exudate was in the pelvis. In

the lower jejunum in the midline just below the stomach and the transverse colon were two perforations on the antimesenteric border not over an inch apart, from which fecal material exuded.

Examination of the involved portion of the intestine after removal (fig. 1 and 2) showed on the peritoneal side the serous coat covered with plastic exudate, containing two cleancut, punched-out, more or less circular perforations, a smaller lower and a larger upper one. The surrounding tissue of the smaller one showed little change; that of the larger, a bluish-black discoloration extending almost

Fig. 1 (case 1).—Peritoneal surface of specimen.

one-half inch about the perforation, especially at the lower border; at the upper border, the omentum was plastered to the intestine up to the perforation but not covering it. On the mucosal surface, however, the involvement was much more marked and extensive. The lower smaller perforation was the same size as on the peritoneal surface. Just above it was a much larger denuded area, a shallow ulcer (partially covered in fig. 2 by one of the valvulae conniventes) with a granulating base, as if the mucosa had sloughed and the area was in process of healing. The perforation in the mucosa at the upper site of the involvement was larger than and not exactly opposite the hole in the peritoneum; to either side of it were two other smaller perforations, while above it, separated by a valvula

connivens, was a row of three other smaller mucosal perforations. The jejunal mucosa was thus completely undermined and separated from the other intestinal coats in the whole area of the six perforations.

CASE 2.—A boy, aged 10 years, was admitted to the hospital on May 30, 1926. An hour and a half before, while playing, he fell off a box car and was struck across the upper portion of the abdomen. He said that he struck a rail; an observer said that he struck a bumper on the car. He complained immediately of severe abdominal pain and tenderness. However, he felt very much better on admission,

Fig. 2 (case 1).—Mucosal surface of specimen.

though he vomited shortly thereafter. He lay on his right side with legs flexed. His temperature was 98 F.; pulse rate, 100; respiratory rate, 36; blood pressure, 92 systolic and 60 diastolic. His general condition appeared good. His abdomen, however, was rigid all over, slightly more on the right, where there was also dulness to percussion. It was decided to observe him for an hour or two. His condition rapidly improved, and operation was not performed. Early the next morning, however, his temperature was 101 F.; pulse rate, 100, and respiratory rate, 40. Vomiting recurred. By midafternoon, his condition was alarming. The temperature was normal; pulse rate, 140; respiratory rate, 40; blood pressure, 72 systolic and 65 diastolic. He appeared very ill, and was irrational. The left side

of the abdomen was now quite lax; the right, however, was rigid and slightly distended with a tender mass in the right upper quadrant and epigastrium. The next morning the boy was better, and by June 2, four days after injury, the storm had completely subsided, and he began to take nourishment. He had spontaneous stools from the second day on with no diarrhea. He was discharged on June 6, with no complaints and apparently in good condition.

On June 12 at 10 a. m., he again was seen in consultation. He had felt reasonably well for three days after discharge, and was up and about and out of the house playing. His mother had permitted him to be very indiscreet in his diet; he had eaten of everything and in very large amounts. On June 10, he had severe abdominal pain with marked distention and some vomiting. His physician gave him morphine, enemas, and applied hot fomentations, and he improved. However, severe pain in the region of the navel, abdominal distention and vomiting soon recurred. On examination, his abdomen was found markedly distended and tense with muscular rigidity and acute tenderness just to the right of the navel. His temperature was 100 F.; pulse rate, 110 and respiratory rate, 24. He was at once returned to the hospital, but his condition rapidly became so critical that the idea of operative intervention was abandoned. About 5 p. m., he complained of severe abdominal pain; his pulse became very rapid and weak; respirations increased; cyanosis and cold sweat appeared; he had an involuntary fluid stool, and vomited a large amount of brown fluid. The whole abdomen was tensely rigid and flat on percussion. Death occurred at 6:30 p. m. on June 12, thirteen days after injury. Necropsy was not permitted.

REPORT OF CASES FROM THE LITERATURE

CASE 3 (Targett [2]).—A man, aged 40, was crushed between a rail of a barge and a crane. He vomited immediately after the accident. On December 1 at 8 a. m., he was admitted to the hospital in a state of collapse. There was considerable tenderness in the lower iliac region and a hematoma in the abdominal wall. He vomited frequently. There was no hematuria. The temperature was 101 F. Opium pills were administered ("Pil. opii. gr. j. 6 tis horis"). On December 2, vomiting continued, the vomitus consisting of brownish material. There was no blood. The abdomen was tender on palpation, but there were no signs of distress. The patient was not at all under the influence of opium. On December 3, the patient was better. Respiration was quiet, and the temperature was normal. There was no pain, and less tenderness. The next day the patient was better and cheerful. He had had no sickness for thirty-six hours. He passed flatus freely. The temperature was normal. At 10 p. m., vomiting came on suddenly. No special pain was complained of, but sickness continued through the night. On December 5, persistent vomiting of brownish material with a fecal (?) odor continued. The patient was very weak and faint. Cold perspiration was noted. The temperature was 98.4 F. On December 6, he was in a state of severe collapse. The pulse was imperceptible. There was occasional sickness. The vomitus was bright yellow. There was a bowel movement. The temperature was 97.6 F. At 8 p. m., when death occurred the temperature was 99.4 F.

Autopsy showed acute suppurative peritonitis with a large quantity of bright yellow fecal material in the abdominal cavity, and gas. There was a rupture in the small intestine 7½ feet (230.5 cm.) from the cecum, the bowel being glued

2. Targett, J. H.: Perforation of Intestine Four Days After Accident, Tr. Path. Soc. London **38**:143, 1887.

to the spine on the left side of the fourth lumbar vertebra. Scybala were found in the cecum and ascending colon. There was no fracture or injury to the other viscera.

CASE 4 (Brewer [3]).—A man, aged 38, was struck in the midportion of the abdomen by a falling bale of paper. He experienced considerable pain at first, but soon recovered; after his admission to the hospital, he presented no evidence of shock. The pulse rate varied between 60 to 70 and was of good quality; slight tenderness was elicited over the epigastric and hypogastric regions and an appreciable degree of muscular rigidity. No vomiting occurred. There were no signs of free fluid or gas in the peritoneal cavity. A diagnosis of visceral injury was made and an immediate operation advised. This was indignantly refused, and the patient insisted that he felt perfectly well and was suffering only from a slight bruise of the abdominal wall. During the following night the pain increased, and the patient became restless and feverish. The next morning, he appeared seriously ill. The abdomen was distended and tympanitic; the liver dulness was not entirely obscured. Tenderness and rigidity were everywhere present. There was flatness in both flanks, which disappeared on changing the position of the patient. The white blood cells numbered 16,000.

Although it was recognized that the outlook was then well nigh hopeless, at the patient's request the abdomen was opened, ether anesthesia being used. As soon as the peritoneal cavity was opened, a large amount of gas and foul-smelling, cloudy fluid escaped, which was found to be a mixture of seropus and intestinal contents. The intestines in the lower half of the abdomen and pelvis were injected and covered by a fibrinous exudate. A large perforation was found in the lower third of the ileum, through which gas and fecal matter were constantly escaping. Several other severely bruised and ecchymotic areas were found on various coils of the small intestine. The rupture was united with two rows of Lembert sutures; the peritoneal cavity was thoroughly irrigated, and the wound closed with two cigaret drains, one leading to the pelvis and one to the right flank. The patient received infusions, and he was generously stimulated. He did exceedingly well for more than a week. The temperature and pulse rate fell to normal, distention and rigidity disappeared, bowel movements occurred and the patient took plenty of fluid food. About the tenth day, he began to complain of pain and signs of a rapidly spreading peritonitis began to develop. Death occurred two or three days later.

Autopsy showed the original perforation to be healed, but a second perforation had occurred at the site of one of the contused areas seen at the time of operation.

CASE 5 (Eve, quoted by Deaver [4]).—A brakeman was injured by falling between the engine and car, his body being caught between the bumpers. He was unconscious for several hours. When Dr. Eve saw him first, he was still suffering from shock, and complained of great pain in the abdomen and back. He had several vomiting spells, the vomitus being dark and of an unpleasant odor, vomiting commencing three hours after injury. Examination of the back and abdomen brought on attacks of nausea, followed by vomiting of dark, offensive, stercoraceous matter. Examination of the back, after the patient became quiet,

3. Brewer, George Emerson: Contusions of the Abdomen Associated with Visceral Injury, Illinois M. J. **48**:70, 1925.

4. Deaver, John B.: The Symptoms, the Diagnosis and the Indications for Treatment of Acute Intra-Abdominal Injuries Without External Evidence of Violence, Railway Surg. **3**:97, 1896-1897.

revealed two large excoriations extending from the ninth dorsal vertebra to the sacrum. There were no excoriations or evidence of internal injury on the abdomen, although it was tympanitic and tender. He had had no action of the bowels for five or six days prior to the injury. The temperature was 101 F.; the pulse rate, 130; respiration, 28. Free evacuation of the bowels was followed by decrease in the pain; the pulse became stronger; the temperature fell to 100 F., and the abdomen became flaccid. Examination of the abdomen at this time gave negative results. The patient slowly improved, and by the end of the fifth week was able to get out of bed and to walk about the room. About the sixth week he complained of some colicky pain in the abdomen, which was attributed to fermentation of food. About the ninth week he suddenly had severe pain in the bowels, accompanied by an audible gurgling sound and a knotting of the intestines, which could be plainly felt through the abdominal walls. Some weeks later a tumescence developed in the hypogastric region, extending to the left inguinal region and reaching as far back as the lumbar region. There was no fluctuation. On the following day, an abscess broke, and a large quantity of pus accompanied by gas of a decidedly fecal odor was discharged. The following day fecal matter escaped through the opening. An operation for relief from the fistula was performed, but the patient rapidly sank and died shortly afterward.

Case 6 (Bunge [5]).—A man, aged 49, had been well except that for several years he had had inguinal hernias which were easily kept reduced and held in place by a truss. While lifting a heavy mass to put it on his shoulder he felt a severe pain in the abdomen, which he localized to the right, but he was not sure. The pain soon subsided sufficiently for him to continue working and during the next thirty-six hours, as was confirmed by his relatives, he felt quite well. Urination and defecation were normal. In the night renewed pain appeared, associated with vomiting. Vomiting became more severe, first of blood (?) and at last of fecal matter. About fifty-four hours after the first attack of pain, he was received at the clinic. He was poorly nourished, with a small but regular pulse (from 100 to 110). The abdomen was not particularly distended, but was quite tender throughout; the abdominal walls were hard as a board. Both inguinal rings admitted the index finger, but no sac was felt on either side. Palpation of the rings, especially the right, elicited marked tenderness. There was dulness to percussion on the left, less on the right. On the left could be seen a markedly distended intestinal loop. By rectum, one felt a sense of resistence in the culdesac; pressure was very painful. Operation was performed immediately. An incision was made in the midline from the navel downward. Foul-smelling exudate immediately welled upward. The intestines were partially plastered together by fibrinous purulent exudate. Palpation of the inguinal rings from the abdomen showed that both admitted the tip of the index finger. There were no definite hernial sacs, but merely slight outpouchings of the peritoneum. Near the right internal ring was a coil of small intestine which contained an opening about the size of a pea. Surrounding the perforation, the intestine was colored bluish red, as if infarcted. The borders of the perforation were fairly smooth and granulating, and the mucous membrane was not prolapsed. There existed, therefore, a defect which appeared as if it had arisen from the sloughing of a necrotic area. The perforation lay about 1.25 meters from the ileocecal junction opposite the mesenteric attachment. It was closed by a two layer running stitch; the abdominal cavity was washed out with physiologic solution of sodium chloride and gauze drainage was inserted.

5. Bunge: Zur Pathogenese der subkutanen Darmrupturen, Beitr. z. klin. Chir. **47**:771, 1905.

Death occurred ten hours later. At necropsy, besides the diffuse peritonitis, there was an encapsulated subphrenic abscess on the right. The intestinal suture was intact.

COMMENT

The foregoing case reports from the literature have been added to my own cases because they illustrate certain variations in the picture of secondary intestinal perforation; that of Targett represents an early perforation four days after injury; that of Brewer, perforation of a contused area after recovery from a primary perforation closed at operation; that of Eve, very late perforation weeks after injury, with formation of abscess and fistula; that of Bunge, perforation from indirect trauma.

Secondary or late perforation of the small intestine from trauma is rare. Demel [5] reported no instance in his study of 126 cases of abdominal injury, and similarly, Hagen [6] none in his 104 cases. Morton,[7] in his tables of 234 cases of abdominal section for trauma, cited only 1 that I can place in this group.[8] It would seem, therefore, that this complication plays but a minor rôle, and that in comparison with either primary intestinal perforation or mild intestinal contusion without perforation it is infequent.

Pathogenesis.—Injury to the abdomen may be local or general. Damage to the intestine from such trauma has generally been divided into three forms: (1) contusion or crushing (écrasement, Zerquetschung); (2) tearing (déchirure, arrachement, Abriss durch Zug); and (3) bursting from increased pressure within the intestinal lumen (éclatement, Berstungsrupture). I discussed this general problem of intestinal injury in a previous publication.[9] In this paper only contusion or crushing is considered, and, indeed, only crushing of such limited severity that primary perforation of the intestine does not occur. Likewise, I am chiefly concerned with local trauma in contradistinction to general, for the latter is often apt to be much more severe; and in these severer injuries other organs are generally included, frequently with profuse hemorrhage and shock, so that intestinal contusion if it occurs is only a small part of the clinical and pathologic picture. In local trauma, however, injury may be easily limited to the midportion of the abdomen. In the cases here reported, it resulted either from a direct blow, or from catching of the body between two

6. Hagen, W.: Ueber Bauchverletzungen des Friedens, Beitr. z. klin. Chir. **51**:529, 1906.

7. Morton, Thomas S. K.: Abdominal Section for Traumatism with Tables of Two Hundred and Thirty-Four Cases, J. A. M. A. **14**:1 (Jan. 4) 1890.

8. Bouilly: Bull. et mém. Soc. de chir., 1883, p. 690.

9. Inlow, W. D.: Abdominal Trauma with Intestinal Injury, J. Indiana M. A. **38**:237 (June 15) 1929.

objects with compression and crushing. Besides types of direct injury, Bunge [5] has shown that a like result can occur from indirect injury. Bunge, in the discussion of his case (case 6), called attention to the fact that there was a definite intermediate stage in which symptoms of a well defined peritonitis were absent following the injury. He therefore reasoned that one of two things happened. There might have occurred a small primary tear of the intestine, which was walled off by adhesions, and a generalized peritonitis occurred secondarily. He considered this explanation improbable. Or the intestine which was pressed into the inguinal ring at the moment of the increase in intra-abdominal pressure was severely injured, but not brought to rupture, and perforation occurred later. In support of this view, he cited both the clinical course and the involvement in the intestine. The perforation definitely appeared as if it had taken place through the sloughing of a sequestrated piece of intestinal wall. If the latter explanation is correct, his case is rightfully one of late perforation, and affords the only example I have been able to find in which such perforation was the result of indirect and not direct trauma.

To produce a contusion or crushing of the intestine, a firm object must push in the abdominal wall with compression of the intestine against a rigid background. Since the locations of such contusions have been found directly over the spinal column, it may be deduced that the latter structure generally furnishes this required background. The intestine is so damaged that perforation occurs either immediately or after a variable length of time owing to secondary gangrene of the wall; thus late perforation generally happens about two weeks after the initial injury. However, in Targett's case perforation occurred in four days and in Eve's, in three months.

Naturally, the severity of the force has much to do with whether the intestine is ruptured immediately or merely contused. Likewise, the tenseness or tautness of the abdominal muscles at the time of impact is important. Generally, the recipient of an abdominal injury is caught by surprise, and the abdomen is lax. Occasionally, however, sufficient time is given for the victim to contract his abdominal muscles and partially dissipate the violence of the blow. It is true also, that a reflex contraction of the abdominal muscles occurs at the moment the object strikes the abdominal wall; but quite often this comes too late to diminish the force of the blow.

In contusion of the intestine, according to Hertle,[10] it is the mucosa that is injured first, while the other layers remain intact. The mucous membrane is crushed over a greater or less extent, the edges of the

10. Hertle, Josef: Ueber stumpfe Verletzungen des Darmes und des Mesenteriums, Beitr. z. klin. Chir. **53**:257, 1907.

wound are often irregularly star-shaped, and the mucous membrane for a distance surrounding is separated from its underlying layers. This separation is well demonstrated in the specimen from my first case. If the crushing injury is more marked, the other intestinal layers are also involved, the peritoneum being generally quite resistent and showing relatively slight defects.

Eichel [11] has studied the effects of localized abdominal trauma in dogs. With the animals anesthetized, even severe blows were innocuous when the feet were tied down tight, regardless of whether the intestinal tract was full or empty. Apparently the stretching of the abdominal muscles made the strongest blow harmless. Only when the hind legs were loosened and the abdomen made lax and blows were delivered in the midline over the spinal column were intestinal and mesenteric lesions secured. Blows in the lumbar region with legs flexed, even during full digestion and after filling the rectum with air, had no effects. However, blows struck dogs that had been operated on and as a result had adhesions to the abdominal wall or between the intestinal coils caused severe injuries.

Von Angerer,[12] in discussing intestinal contusions, remarked that they are recognizable by suggillation and ecchymosis in the intestinal wall and the bluish color of the serosa. Surgeons have the opportunity to see such contusions when forced efforts at taxis have been made in incarcerated hernias. The degree of severity of such contusions is difficult to judge, but he stated that one is accustomed in general to attach no undue importance to them when the serosa is intact. However, if tears can be recognized in the mucosa and in the muscularis, the danger of a later perforation is very great. The first case here reported would seem to belie this statement. The serosa was intact at the time of the exploration and the intestine seemed viable, but perforation occurred nevertheless. However, there is probably another factor besides that of mere contusion or crushing of the intestine that contributes materially to the necrosis of the intestinal wall and ultimate perforation. This contributory factor is distention.

When a portion of the intestine is contused, the area involved is so crippled and paretic that when it is called on to do work, as when the patient is fed, it is unable to contract properly and acts as a point of obstruction. Following this, the intestine above the lesion becomes markedly distended, as may readily be seen in the clinical histories here given. I quote from Van Beuren: [13]

11. Eichel: Klinischer und experimenteller Beitrag zur Lehre von den subkutanen Darm-und Mesenterium-Verletzungen, Beitr. z. klin. Chir. **22**:219, 1898.

12. Von Angerer: Ueber subcutane Darmrupturen und ihre operative Behandlung, Arch. f. klin. Chir. **61**:970, 1900.

13. Van Beuren, Frederick T., Jr.: The Mechanism of Intestinal Perforation Due to Distention, Ann. Surg. **83**:69, 1926.

Distention of the intestine increases its diameter. Any increase in its diameter is tripled in its circumferential measurement. . . . A moderate increase in diameter, therefore, results in considerable stretching of the wall. The intestinal vessels pass between the layers of the wall along its circumference from their origin at the mesenteric border to their terminal anastomoses at the antimesenteric surface, becoming progressively more thin-walled and more narrow of lumen. Because they are elastic the stretching of the intestinal wall from distention still further thins the vessel walls and narrows the vessel's lumen like a stretched rubber tube. At the same time the pressure from within the intestine tends to flatten out the vessel's lumen. The narrowing of the vessel's lumen and the thinning of the vascular wall are maximum at the antimesenteric surface of the intestine where the terminal anastomoses occur; and, the distention pressure being constant throughout the lumen of the intestine, the maximum effect is seen at the antimesenteric surface where a union of the three factors of pressure, thin wall and narrow lumen finally results in obliteration of the vessel. This obliteration occurs sooner in the vein than in the artery on account of the less resistant wall. The blood continues to pour through the arterial vessel until the pressure against the obliterated vein suffices to rupture the vessel wall and permit extravasation and coagulation. Finally, the pressure occludes the artery as well as the vein. The area of tissue supplied by these terminal vessels is thus deprived of circulating blood and necrosis occurs. This necrosis is usually first evident in the submucosa and inner muscular coat, but rapidly extends to the other coats of the intestinal wall, and perforation may occur within twenty-four hours after the discoloration due to the hemorrhagic infarct has been first noticed.

Further, the question may be asked, what rôle if any do the intestinal digestive juices play in the causation of perforation? I have no definite data on this point. Doubtless, in the lower ileum this factor can be disregarded, and it is in this location that most of these perforations occur (in four of six cases here reported). But in the jejunum, the question may deserve more consideration. Case 1 comes under this category. As seen in figure 2, the healing ulcer on the mucosa below the areas of perforation looks not unlike a shallow peptic ulcer, and the thought naturally arises that tryptic activity may have had some part in its causation. In this connection, a case reported by von Huebschmann [14] is of interest. A boy, aged 4½ years, suffered a slight abdominal trauma four weeks before death. Following the injury he had persistent intestinal bleeding, and finally peritonitis with a fatal outcome. At necropsy, a perforation of a Meckel's diverticulum, which was entirely coated with gastric mucosa, was found. Presumably a tear in the mucous membrane caused by the trauma was converted into an ulcer through peptic action which later led to perforation. This, of course, is a case illustrating the now comparatively well

14. Von Huebschmann: München. med. Wchnschr., September, 1913, pp. 2051-2052; quoted by Stulz and Voringer: Peptic Ulcer of Meckel's Diverticulum, Ann. Surg. **83**:470, 1926.

known picture of peptic ulcer of this diverticulum; but it is of interest that peptic activity, and not distention, added to the trauma played the decisive rôle in leading to perforation.

Clinical Course.—There are no distinctive symptoms of intestinal injury. Trauma to the abdomen varies in severity from mere slight contusion of the parietes through various degrees of intestinal contusion to severe ruptures of the intestinal tract; and often it is difficult to know how extensive the damage is. Furthermore, the picture may be obscured by injuries to other organs, with hemorrhage. Yet on the whole, those cases in which only intestinal contusion occurs show a less severe degree of trauma and a less striking clinical course than those in which primary perforation takes place. Yet at times the gravest lesions may exist with few symptoms. Indeed, abdominal trauma in its initial phase should be considered as a whole, and contusion and primary perforation separated only at the operating table. The clinical course may conveniently be divided into three stages: an initial, an intermediate and a terminal.

In the initial stage, the patient enters the hospital with the history of having suffered abdominal trauma of varying severity. This history, however, may be entirely lacking as in case 1, in which the blow received seemed so trival to the patient that he did not even mention it. Pain, often severe, diffuse or located in the midportion of the abdomen, is the most constant symptom. Vomiting may occur. There are generally no external evidences of injury to the abdominal wall. Among the foregoing cases only one showed excoriations, and these were on the back. Abdominal tenderness is invariable, and together with the pain, constitutes the most reliable sign. It may be diffuse or localized to the area of injury. Rigidity and distention may or may not be present. Heineke [15] has discussed marked meteorism coming immediately after abdominal trauma. This he attributed to injury to the retroperitoneal nerve plexuses. It generally occurs in mild injuries and is absent in severe visceral lesions until the onset of peritonitis. Generally the temperature is at first normal, though the pulse and respiratory rate may be accelerated. Soon, however, the temperature rises, but seldom above 101 F. The symptoms may become alarming, as for example in case 2, and if expectancy has been practiced, one judges he has erred in not opening the abdomen, that a perforation has been present, and that fatal peritonitis is developing. Yet this storm may subside almost as rapidly as it came.

The intermediate stage is one of relative quiescence. The danger seems to have been safely passed, and all concern is lost with conse-

15. Heineke, H.: Ueber Meteorismus nach Bauchcontusionen, Arch. f. klin. Chir. **83**:1104, 1907.

quent relaxing of the previous careful observation. The patient may be dismissed from the hospital and forgotten, only to be later readmitted in an agonal state. Yet tokens of the impending catastrophe are presented if they are only read correctly. With the least dietary indiscretion, pain recurs. Intermittent distention persists past the time at which it seems it should have completely disappeared. Diarrhea may occur and blood may be found in the stool. This intermediate stage is of variable duration, generally lasting from ten days to two weeks; exceptionally, from four days (case 3) to three months (case 5).

In the terminal stage, perforation occurs. Pain is very severe; it is that of perforated peptic ulcer. This is in marked contrast to the pain of primary intestinal perforation, when the patient may insist that there is nothing wrong and refuse operation. Following perforation, the symptoms are those of a fulminating and rapidly fatal peritonitis. Vomiting recurs and soon becomes fecal. The abdomen is distended and rigid, and may be flat to percussion. The pulse rate rises. The blood pressure falls. Cold sweat and cyanosis appear. There may be involuntary stools. Death swiftly follows. The loss is dramatic, coming as it does after apparent recovery from the intial injury. After perforation, the hopelessness of the situation is only too evident, and generally no intervention is attempted.

However, the course as depicted is not always followed. Perforation may not occur until after several weeks, and may be so slow that the area can be walled off by adhesions, and produce only a localized abscess or fecal fistula.

Prognosis.—It is probable that mild contusions of the intestine are much more frequent than those progressing to secondary perforation. Many of these are not, and often cannot be diagnosed without exploratory laparotomy. Often patients with such injuries do not even consult a physician. At times, however, symptoms from intestinal contusion have been sufficient to lead surgeons to open the abdominal cavity, fearing that a serious visceral lesion existed. In such cases, exploration has given negative results with the exception of a bruise on the intestine, and prompt and satisfactory recovery has occurred on simply returning the intestine to the abdomen without further intervention. On the whole, then, the prognosis of intestinal contusion is favorable, most patients recovering without treatment. Hopp[16] reported four such cases of simple contusion in which operation was not performed and the patients were dismissed from the hospital in from six to fifteen days. Even in those cases in which symptoms do not promptly subside, the outlook is probably fairly good if the danger is recognized

16. Hopp, Max: Ueber die Indikationsstellung bei traumatischen subkutanen Bauchverletzungen, Beitr. z. klin. Chir. **72**:278, 1911.

and the intestine is put at rest or operation performed. Blood in the stool is inconstant, but even when it is present it is not necessarily of bad prognostic import or necessarily indicative of impending perforation. It may indicate merely superficial mucosal ulceration which will readily heal. Hopp cited a case in point.

Yet when secondary perforation has occurred, the outlook seems hopeless. Death occurred in all the cases here reported, and a similar outcome has been reported in all other cases that I have found in the literature. Operation, even when done immediately, seems to be of little avail. In one of Hopp's three cases, operation was performed immediately with a fatal outcome. One would expect, however, that in some cases of very late perforation with abscess or fistula formation the outcome would be more happy than in Eve's case (case 5).

Treatment.—As may readily be seen from the discussion on prognosis, the treatment for secondary intestinal perforation from trauma is prophylactic rather than curative. All effort must be directed toward the prevention of the catastrophe of perforation. The most important desideratum in this connection is the knowledge of the possibility of this contingency, the factors in its causation and the signs of its imminence. Had I been sufficiently conversant with this syndrome, the patients in the two cases here reported would not have been dismissed from the hospital, indiscretions in diet would have been avoided, and secondary intervention would have been resorted to before perforation. In extenuation it might be said that in the first case no history of injury was elicited, and every one was entirely at sea as to the nature of the underlying pathologic process. In the second case, no such excuse is possible; indeed, still further censure could be made in that exploratory celiotomy was not made at the time of injury.

I need not discuss in detail the treatment of the first stage, since it is that of abdominal injury in general. The patient should be hospitalized. Shock, if present, should be promptly combated. The abdomen should be immobilized by a binder. Morphine should be used sparingly, especially in cases in which exploration is not done immediately for thus the progress of the case may be unduly masked. If there are good grounds for suspicion of visceral injury (pain, rising pulse rate, tender and rigid abdomen, especially over a limited area), exploration should be made at once. At this intervention, primary intestinal rupture may be found or areas of contusion associated with such rupture or merely intestinal contusions alone. In the second of these, it is not sufficient to repair the rupture alone and disregard the areas of contusion. These accompanying contusions should receive the same careful attention that they would if they were the only lesions present. The peril inherent in these contusions is well shown in Brewer's case

(case 4), in which, after successful repair of a primary intestinal perforation, a secondary perforation occurred ten days later at the site of a contused area seen at operation.

It is the treatment of the second or intermediate stage of abdominal trauma that especially belongs to a discussion of secondary intestinal perforation. The prodromal symptoms of perforation (pain, vomiting, diarrhea, blood in the stool, localized tenderness, meteorism) should be carefully watched for, and on their first appearance, the intestinal tract should be put at rest. All foods should be promptly discontinued, and the patient given fluids by rectum or under the skin. Hertle [10] advised continuance of this fast for five days. If the symptoms promptly subside, careful resumption of diet should be made, starting with liquids. Marked distention, if present, should be relieved by enemas, since such distention is probably more dangerous than any peristalsis so set up. Narcotics should be used sparingly, especially during the observation period. If the threatening symptoms do not promptly subside, or if after subsidence they reappear on the least attempt at feeding, intervention would seem to be indicated, though I have found no case in the literature in which this has been carried out before perforation. At operation, the area, if small, may be turned in by suturing, or covered by omentum or sutured to some peritoneal surface (parietal peritoneum); if large, it should be resected.

This has been tried out by Thomson [17] in experiments on dogs in which portions of the wall of the intestine were excised. He has shown that small lesions not larger than 1 cm. square can be safely sutured over, provided the surrounding tissue is normal. Larger defects, if resection cannot be carried out or is difficult, can be handled by a plastic operation with fixation of the intestine to an adjacent peritoneal surface so long as an acute knuckling is avoided. However, deep intestinal defects, even if of small extent, where the surrounding wall is pathologic, should be treated by resection; if this is not possible, a plastic covering should be made and gauze drainage instituted. In my first case mere covering of the involved area of intestine at the time of operation might have converted the case from one of free peritonitis after perforation to a localized abscess which later could have been successfully drained. The effort made by the tip of the omentum to plug the upper perforation can be seen in figure 1. In cases of marked distention, ileostomy above the lesion should be considered.

Treatment at the third stage after perforation seems hopeless. Possibly immediate intervention with closure of the perforation and drainage may in the future show better results than in the past, for

17. Thomson, Hermann: Ueber nicht perforierende, peritoneale und muskulaere Darmlaesionen und deren Behandlung, Ztschr. f. Geburtsh. u. Gynäk. **26**:163, 1893.

this effort has only occasionally been made, and there are not enough available data to enable one to come to final conclusions.

SUMMARY

1. Six cases of secondary or late perforation of the small intestine from trauma are reported, two personal, and four illustrative ones from the literature. On the basis of these reports, a clinical discussion of the condition is given.

2. Secondary perforation results from the necrosis and sloughing of an area of the intestinal wall, on the antimesenteric border, which has been contused, generally either from direct blows over the mid-portion of the abdomen or from crushing. Intestinal distention is a contributing factor. Perforation occurs most frequently about two weeks after injury.

3. The initial symptoms are those of abdominal trauma in general. After apparent recovery, there are symptoms in the intermediate stage suggesting the possibility of late perforation; these are recurring pain and tenderness, vomiting, meteorism, diarrhea and blood in the stool. The pain of perforation is similar to that of perforated peptic ulcer. A fulminating and rapidly fatal peritonitis ensues.

4. The prognosis of simple intestinal contusion is good. Most such contusions heal without being diagnosed. When necrosis with secondary perforation occurs, however, the outlook is bad, all the cases here reported having proved fatal.

5. The initial treatment is that of abdominal trauma in general. If visceral injury is suspected, exploration should be performed at once. Areas of contusion should be protected by being turned in if very small or covered by omentum or sutured to the parietal peritoneum if larger. Primary resection is required only occasionally. In the intermediate stage perforation may be guarded against by a careful dietary regimen, with periods of absolute withdrawal of food if necessary. Patients should be kept in the hospital until all danger is past.

THE PROBLEM OF CANCER OF THE STOMACH*

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DETROIT

That cancer of the stomach is a problem, and can be considered a major problem in the control of cancer, is evident when one considers the figures of the annual toll of cancer in this part of the body, how little actually is accomplished for the patient with cancer of the stomach and what might possibly be done for him.

The general facts are well known. Almost 35 per cent of all deaths from cancer are due to cancer of the stomach; the disease picture is easily recognized when well developed; large series of successful primary removals have been reported, yet the general hopelessness and pessimism of most laymen and physicians are only too apparent.

This study is based on an analysis of 365 consecutive deaths from cancer of the stomach, collected through the Cancer Division of the Department of Health. Of these patients, 213 were observed in hospitals and 152 were not.[1] The points borne in mind were: (1) the present average situation as regards diagnosis and treatment, (2) the chief difficulties and commonest errors in both recognition and therapy and (3) the possibilities for improvement and control.

THE AVERAGE CARE

It is easily seen that, viewing the average situation as regards diagnosis and treatment, the popular pessimism concerning cancer of the stomach is well founded (table 1). In other words, just 3 per cent of those who died had had the chance of cure which operative recovery from radical resection represents. The series covered one and a half years and included all deaths registered as having been caused by cancer of the stomach in a population of 1,730,000 during that time. As indicated in previous studies, this can probably be considered an average situation; it is believed that similar tabulations in most of the com-

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1. All deaths were certified as having been due to cancer of the stomach. In many instances, the diagnosis was made clinically only, so that a certain amount of scientific accuracy may be lacking in these analyses; however, a death with dyspepsia, vomiting, loss of weight, epigastric mass, etc., was considered certain enough to have been caused by cancer to be included for analysis. Unless the cases which had had only clinical observation showed these manifestations, they were not included.

munities the country over would show similar figures; so that, as regards the average possibilities of accomplishment, the start can be made almost at the level of zero.

THE CHIEF DIFFICULTIES AND COMMONEST ERRORS IN RECOGNITION OF CANCER

Though some well qualified internists still insist that cancer of the stomach cannot be recognized by present diagnostic methods early enough for any accomplishment in radical treatment, nevertheless authors of textbooks are rewriting the text on symptomatology of this type of cancer,[2] leaving out the description of the terminal condition—mass, vomiting, loss of weight, pain, etc.—and describing the early mild manifestations. It is well recognized that one of the chief factors in any possible improvement in the treatment of cancer of the stomach will be earlier recognition.

TABLE 1.—*Care Given in a Series of Fatal Cases of Cancer of the Stomach*

Total number of deaths from gastric cancer	365
Total number in hospitals	213
Total number of operations	96
Exploration only	29
Gastro-enterostomy	35
Gastrostomy, etc.	4
Resections	28
Total primary recoveries from radical operations	11 or 3%

Three hundred of these 365 charts were analyzed. The first symptoms given in the 300 histories were studied. The histories of patients with cancer of the stomach can easily be divided into those which indicate a previous indigestion of several years' duration of more or less severity and those in which the cancer started suddenly from apparently good health. Of 287 cases in which such data were obtained, 71, or 24.7 per cent, started from long preceding indigestion. The remaining 216, or 75.3 per cent, started suddenly from previous good health. This shows a somewhat larger number starting from preceding indigestion than a previous analysis[3] (based on fewer cases) showed, and it is slightly higher than the number given in many reports. However, any large series of cases of cancer of the stomach will show 15 per cent or more starting from long continued preceding indigestion.

We shall consider first the larger group, the 75 per cent which started from previous good health. Table 2 lists the first symptoms complained of, in the order of their frequency, and divided further

2. Tice: Practice of Medicine, Hagerstown, Md., W. F. Prior Company, 1922, vol. 7, p. 496.

3. Saltzstein, H. C., and Sandweiss, D. J.: The Average Treatment of Cancer, Arch. Surg. **18**:2176 (April) 1929.

into those referable to the upper part of the alimentary tract—indigestion, history of ulcer, etc., presumably easier to recognize—and those not so definitely referable to the stomach and more atypical, as loss of weight, weakness, etc.[4]

Thus, 69 per cent started with symptoms which, though often mild, were distinctly referable to a pathologic disturbance in the upper part of the abdomen. The chief problem is not the recognition of the symptoms, but the arousal of suspicion that they may be of serious import. As McCarty expressed it:[5] "Small cancers of the stomach

TABLE 2.—*First Symptoms Complained of by Two Hundred Thirteen Persons Who Died of Cancer of the Stomach (Onset from Previous Good Health)*

Symptoms Referable to Upper Part of Alimentary Tract		Atypical Symptoms	
Indigestion	74	Loss of weight, weakness	37
Pain in epigastrium	21	Loss of appetite	14
History of ulcer	20	Atypical pain (not in upper part of abdomen)	11
Vomiting	15	Anemia	2
Gastric hemorrhage	3	Diarrhea	2
Difficulty in swallowing	5		
Gnawing sensation in epigastrium	3		
Distended abdomen	3	Total	66 or 31%
Fulness in stomach	3		
Total	147 or 69%		

TABLE 3.—*Contrasting Symptoms of Onset of Pyloric Cancer with Symptoms of Growths Starting Elsewhere in Stomach*

Cases	Location	Onset with Dyspepsia, %	Onset with Atypical Symptoms, %
55	Pylorus	70.3	29.7
36 *	Elsewhere	33.3	66.7

* Lesser curvature, 13; cardia, 8; pars media, 4; greater curvature, 3; lesser and greater curvature, 3; lesser curvature and cardia, 3; fundus, 2; total, 36.

do not give signs and symptoms differing from those of chronic gastric ulcer, duodenal ulcer and sometimes disease of the gallbladder."

The number of cancers of the stomach that start suddenly with vague and atypical symptoms has given rise to a good deal of pessimism regarding the possibility of diagnosis early enough for radical treatment. When one considers this in the light of the anatomic location, the popular pessimism must be diluted.

In 91 of these cases with suddenly appearing indigestion, the anatomic lesion was known with certainty.[6] Table 3 shows that 29.7 per cent of the pyloric cases started with ayptical symptoms, contrasted

4. Data were incomplete in three cases, leaving 213 for analysis.

5. McCarty, W. C.: Cancer Research **12**:1 (March) 1928.

6. Cases in which the anatomic site of the lesion was not clearly stated, as "pylorus and greater curvature," etc., or in which the site was not known with certainty, were excluded.

with 66.7 per cent of those located elsewhere (lesser curvature, fundus, cardiac, etc.) starting atypically. As is shown in table 9, most of the growths resection of which was attempted were in the pylorus and distal portion of the stomach, so that as regards possibility of control, the pylorus and right half of the stomach is the important part.

That pyloric growths are twice as apt to start with typical symptoms as those elsewhere in the stomach, and that numerically more of the cancers that start with insidious unrecognizable symptoms are in non-resectable locations can only be facts of hopeful import when one is considering the control of cancer of the stomach.

Danger of Confusing Ulcer and Cancer.—The argument as to whether ulcer precedes cancer of the stomach frequently enough to make medical treatment of gastric ulcer dangerous still waxes heatedly.

TABLE 4.—*Symptoms of Onset of Cancer in Seventy-One Patients Who Had Had Long Continued Preceding Indigestion*

Onset of Cancer Symptoms Marked by	Preceding Symptoms Typical of Ulcer	Preceding Symptoms of "Dyspepsia"	Total
Recurrence of indigestion	9	6	15
Intensification of indigestion	7	32	39—76%
Weakness, loss of weight	2	5	7
Hemorrhage	1	1	2
Anorexia	0	1	1
Vomiting	1	3	4
Atypical pains	1	2	3—24%
	21	50	71—100%

Most pathologists, studying gastric cancers at autopsy or resected gastric ulcers, feel that the possibility of gastric ulcer developing into cancer is unusual, from 3 to 6 per cent being often quoted estimates. Surgeons have frequently estimated the possibility much higher, from 10 to 20 per cent or even more.

As noted, 71, or 24.7 per cent, of the total number of cases were preceded by a long continued indigestion, before symptoms of what was considered as the onset of cancer supervened. To be sure, there is no way of knowing whether these were gallbladder dyspepsias, slowly growing primary cancers, cancers developing on an irritable stomach or gastric ulcers that later developed into cancer. Since in most of these cases the preceding indigestion was of more than three years' duration and the average total duration of illness in all of the 287 cases was 15.6 months, it is not felt that many slowly growing primary cancers were included.

The symptoms of onset of 71 cancers that developed from preceding indigestion which may or may not have been due to ulcer are analyzed in table 4. In 76 per cent the only onset of what might have been the

change from ulcer to cancer was a recurrence of the symptoms after the lapse of a free interval or a sudden intensification of these symptoms. In 24 per cent, the probable onset of cancer was marked only by weakness and loss of weight, anorexia, hemorrhage, vomiting or atypical pain.

One third (21) of these cases of cancer with a long continued preceding indigestion were marked by typical postprandial pains relieved by alkalis and food. Over one half of these with the history of ulcer (14) had been clinically diagnosed ulcer, and presumably the patients had been treated for ulcer. Several of the patients had had medical management for ulcer within a few months of the positive diagnosis of cancer. Six had previous gastro-enterostomies (including 2 of the 14 who also had medical management for ulcer).

In addition to the cases just mentioned, 21, or 10 per cent, of the 216 cases that started suddenly from previous good health, had what was noted as "ulcer history." (This makes 15 per cent of the total 300 cases, which had "ulcer history" definite enough to be described as such).

One cannot review these records without feeling that the practical problem of clinically confusing gastric ulcer with cancer is much more frequent than is represented by the estimate of 6 per cent. Generally, the cancer developed under the eyes of physicians other than those who treated the patient for ulcer, and many of these cases would not come to the pathologist studying his hospital or autopsy material in regard to gastric ulcer and cancer, for in the second instance the cancer was well developed and its origin from possible ulcer obscured. Frequently, there being no second operation or autopsy, the diagnosis of cancer can be made only clinically and hence is always open to the criticism of the lack of scientific evidence.

The following cases are typical of the latent danger in conservative treatment for chronic gastric ulcer:

CASE S155.—A woman, aged 61, had a gastro-enterostomy in January, 1922, for pyloric ulcer, following a history of peptic ulcer distress for thirty years. In January, 1925, three years after operation, there was a recurrence of abdominal pain, with vomiting, hematemesis, blood from the bowels and loss of weight. The patient refused operation for a suspected recurrence of the ulcer, and continued to lose weight, and to vomit, had severe abdominal pain, developed a mass in the epigastrium and died in October, 1927, of what was clinically considered gastric carcinoma. There was no autopsy.

CASE S52.—A man, aged 53, had had indigestion—belching, flatus, etc.—for twenty-six years, for which gastro-enterostomy for pyloric ulcer was done in 1924. He felt perfectly well, was free from all pain and indigestion for one year after operation and gained from 109 to 145 pounds (49.4 to 65.8 Kg.) in weight. One year after operation, cachexia began. There was a rapid loss of weight. Jaundice was marked during the last month of his life. He died in

May, 1927, two years after the onset of recurrence with what was clinically considered gastric carcinoma. There was no autopsy.

The chief problem is, just as it is with the lump in the breast, how often can one be sure that the lesion is benign without removing it?

Alvarez [7] analyzed some of the factors that tend to minimize in the minds of laity and physicians the frequent association of these two lesions. Gastric ulcer is relatively a rare disease. Large gastric ulcers are still rarer. Ninety-two per cent of the excised gastric ulcers are smaller than a 25 cent piece (2.4 cm.). Also, 75 per cent of observed cancers of the stomach are larger than 4 cm.; few are smaller than 2 cm. Practically, large gastric ulcers (over 2.4 cm.) or small cancers (smaller than 2.4 cm.) are so rare that a physician may not see one for several years, and hence is not often confronted with the clinical problem of differentiating gastric ulcer from cancer. But all cancers must be small at some time in their history. Alvarez estimated that on the basis of size alone a lesion in the stomach the size of a dime (1.8 cm.) has one in fifteen chances of being malignant. If it is the size of a quarter (2.4 cm.), there is one in ten chances of its being malignant. When it reaches the size of a half dollar (3 cm.) there are two chances to one that it is cancer, and when it is larger than a dollar (3.5 cm.) it is almost certainly cancer.[8]

Roentgen Diagnosis.—Sixty per cent of these 300 cases were examined by means of the x-ray. In 30 per cent of the cases note was made that no x-ray picture had been taken. The data on the remaining 10 per cent do not indicate whether or not roentgenologic examination had been made.

As seen from table 5, 82.5 per cent of those who had been observed in hospitals had had roentgen examination, while only 26.1 per cent of those not in hospitals had had roentgen examination. The large number of patients with cancer of the stomach who die without ever having been in a hospital and without ever having had a roentgen examination or adequate diagnosis is perhaps not sufficiently appreciated. Many of

7. Alvarez, W. C.: Sizes of Resected Gastric Ulcers and Gastric Carcinoma, J. A. M. A. **91**:226 (July 28) 1928.

8. Dr. Jordan of the Lahey Clinic has divided gastric ulcers into tractable, those healing within two or three weeks with complete disappearance of x-ray niche and return to normal tonus of the stomach wall; and intractable, those which do not heal completely in two weeks. Patients with the latter condition only are operated on, about 30 per cent of those with gastric ulcers seen in their clinic. This may be a valuable method of safely avoiding such a formidable operation as resection of a gastric ulcer in many cases. However, the total number of cases is not as yet large, and it is difficult, in the average situation, to obtain such accurate medical and roentgenologic study and to have patients report regularly for follow-up examination over a long period of time. See Jordan, Sarah M.: Gastric Ulcer and Cancer, J. A. M. A. **93**:16 (Nov. 23) 1929.

these patients were seen by a physician only a few times in the terminal stages of the disease. Others had refused suggested complete examination.

In 5 of the 172 cases in which roentgen examination had been made, the roentgenologic reports were not obtained, leaving 167 for analysis. In 67 per cent, the roentgenologist diagnosed cancer positively. In another 19.8 per cent, the diagnosis was either ulcer or cancer, ulcer and cancer, probable cancer or syphilis and cancer, making

TABLE 5.—*Number of Persons Who Had Roentgen Examinations*

	Cases	Roentgen Examination	No Roentgen Examination	No Data Concerning Roentgen Examination
Total number of cases	287	172 or 60%	84 or 29.2%	31 or 10.8%
In hospital	172	142 or 82.5%	8	22
Not in hospital	115	30 or 26.1%	76	9

TABLE 6.—*Results of One Hundred Sixty-Seven Roentgen Examinations of Persons Who Subsequently Died of Cancer*

Results of Examination	Cases		Percentage for Comparison
	Number	Percentage	
Positive cancer	112	67.0	72.3 McVicar
Ulcer or cancer	13	7.8	0.4 and Daly
Probable cancer	13	7.8	
Syphilis or cancer	3	1.8	
Pyloric or duodenal cancer	2	1.2	
Cancer and ulcer of cardia	1	.6	
Cancer or ulcer	1	.6	
Total positive or suspected cancer	145	86.8	
Result negative	6	3.6	1.2
Gastric ulcer (no reference to cancer)	5	3.0	7.5
Result of 1st examination negative; of 2nd, positive	4	2.4	
Duodenal ulcer	2	1.2	1.0
Result not definite	2	1.2	17.6 misc. lesion
Ulcer at gastroenterostomy of stomach	1	.6	
Extragastric pressure	2	1.2	
Total misleading	22	13.2	

86.8 per cent positive or suspected cancer. In 13.2 per cent, the x-ray picture was definitely misleading (table 6).

This estimate of the accuracy of roentgenologic diagnosis of a malignant gastric condition agrees rather closely with the much larger experience in the Mayo Clinic recently reported by McVicar and Daly.[9] In their 1,104 cases of gastric cancer in which roentgen examination had been made, the result was positive in 72.3 per cent, compared with 67 per cent in our cases. Though further comparisons are difficult because of the difference in terms used, it is evident that there was

9. McVicar, C. S., and Daly, Joseph: Diagnosis of Operable Cancer of Stomach, Ann. Int. Med. **1**:152, 1927-1928.

a similar small percentage in which the lesion was placed in the duodenum, a small number (smaller than in our series) in which the result of roentgen examination was negative and a larger number in which gastric ulcer was diagnosed.

Twenty of the 22 cases (13.2 per cent) in which the x-ray picture was definitely misleading are detailed in table 7: In seven cases the result of the roentgen examination was negative, sometimes within one month of death from cancer. In 4 cases, one x-ray picture was negative and a second positive; in 2 of these, the cancers were in the cardiac region. In 1, the x-ray picture was not definite. In another, the cancer had perforated, and the large abdominal abscess surrounded by viscera was taken to be an extragastric neoplasm. Five cases were diagnosed gastric ulcer; in 2 of these, gastro-enterostomy had been performed, to be followed after some months by the clinical picture of carcinoma. Two cases with marked obstruction were thought roentgenologically to be duodenal ulcers. From this, it can be seen that one month before death from carcinoma of the stomach the x-ray picture can be negative. The cases in which the roentgenologist diagnosed ulcer with no noted suspicion of cancer either were at the pylorus and accompanied by obstruction (4 cases), or were ulcer craters on the lesser curvature (2 cases). The cases in which mistakes were made in the roentgen diagnosis were not preponderantly in the left half of the stomach, where no premium is placed on accurate diagnosis, but in anatomic locations where resection is possible.

The lesson taught is that, although the x-ray picture is helpful in the early diagnosis of a malignant condition, the roentgenologic diagnosis is not accurate enough to be used to the exclusion of other clinical interpretations. Given a mildly but definitely suspicious clinical history of gastric malignancy, a negative diagnosis by means of the x-ray should not entirely rule out cancer.[10]

THE CHIEF DIFFICULTIES AND ERRORS IN TREATMENT

As was noted in previous studies,[3] the mortality from gastro-enterostomy is about as high as that from resection. It is being appreciated lately that gastric resection, if at all feasible, is a better palliative procedure than gastro-enterostomy; patients are more comfortable following it, and patients with nodules in the liver have lived three years after gastrectomy for cancer. Also, glands in the lesser omentum are frequently inflammatory when thought to be cancerous. The problem in the treatment of persons with gastric cancer, then, is doing more gastric resections with a much lower mortality.

10. J. C. Bloodgood (in Lewis, Dean: Practice of Surgery, Hagerstown, Md., W. F. Prior Company, 1928, vol. 6, chap. 8, p. 84) mentioned the possibility of a roentgenologic examination overlooking malignancy, citing two instances.

TABLE 7.—*Twenty Fatal Cases of Cancer of the Stomach in Which Roentgenologic Diagnosis Was Misleading*

	Roentgen Diagnosis	Final Condition
Cases in which result of examination by x-ray was negative (7).		
No. 590	Diseased appendix 1 month before death	Cancer of pylorus (operation, autopsy)
No. 28	Negative 1 month before death	Cancer of stomach (autopsy)
No. 556	Negative 1 month before death	Cancer in ulcer with metastases
No. 407	Negative 1 month before death	Adenocarcinoma of lesser curvature
No. 404	Negative 1 month before death	Cancer of pylorus (autopsy)
No. 113	10-3-29: Stomach fills readily; pyloric end pulled over to gallbladder region; no filling of cap; no 5 hr. retention	Autopsy 10-5-29: Almost complete contriction of pyloric ring 1 cm. in width; microscopically adenocarcinoma
No. 200x	10-16-29: Negative; no evidence organic lesion of esophagus, stomach or duodenal bulb	Operation 1 week later; extensive cancer of lesser curvature with metastasis in lesser omentum; death, Dec., 1929
Cases in which result of 1st examination was negative; of 2nd, positive (4).		
No. 302	March, 1927: Negative. Feb., 1928: Cancer of cardiac end of stomach	
No. 397	1926: Negative; diet, etc., prescribed. Six months later: Lesion of stomach	Operation; carcinoma of midportion of greater curvature
No. 22	5-20-27: Perforated ulcer with no evidence suggesting cancer; perforation due to extragastric pressure; 2nd x-ray picture: Advanced cancer of stomach, probably inoperable	
No. 215y	1st x-ray picture: Ulcer at cardia; a malignant condition to be considered. Patient then went to a nationally known clinic, where, although esophagoscopy showed slight suspicious lesion at the cardia, x-ray picture was negative	Operation 7 months later; large cancer mass found in the cardiac region of stomach with crater in lesser curvature
Case in which x-ray picture was not definite.		
No. 474	Jan., 1928, x-ray picture negative; stomach and duodenum cap; gallbladder suspected; clinical diagnosis; typical duodenal ulcer; patient benefited with Sippy diet and rest, etc. May, 1928: Stomach large; marked hypertrophy of rugae of greater curvature	Operation 5-18-29; tumor mass, size of lemon, involving cardiac end of stomach
Case of extragastric pressure.		
No. 616	12-27: no intrinsic gastric lesion; defective shadow in greater curvature at antrum due to pressure caused by palpable tumor mass; palpation revealed stomach and entire enteric tract thrown more to left on account of the mass in right upper and lower quadrants; stomach seemed fixed above mass	Operation; large abscess surrounded by intra-abdominal viscera; new growth invasion of intestines and abdominal wall; microscopically adenocarcinoma of stomach, degenerating
Cases in which roentgen diagnosis was gastric ulcer (5).		
No. 162	Crater of large ulcer on lesser curvature; hour-glass deformity of stomach	Operation; tumor mass in stomach; liver involved
No. 472	Incisure of greater curvature of stomach with slight irregularity opposite suggesting gastric ulcer	Operation; tumor mass involving entire lesser curvature
No. 52	Gastric ulcer; gastro-enterostomy performed	Symptoms of cancer started 1 year later
No. 501	Definite defect of pylorus, which is constant; dilatation of stomach; marked residue after 6 hrs.; diagnosis: ulcer of pyloric and duodenal junction	Massive cancer of pylorus; operation
No. 525z	Gastric ulcer; gastro-enterostomy performed	Subsequent modified Sippy management for epigastric distress; operation 8 mo. later; extensive cancer of lesser curvature
Cases in which roentgenologic diagnosis was duodenal ulcer (2).		
No. 400	Duodenal ulcer with obstruction	Operation; of cancer of stomach, with metastases to lymph nodes
No. 506	Marked obstruction in duodenum with 50% retention in 23 hrs.	Large indurated pyloric cancer

Table 8 shows that the patients with resections had symptoms for 8.1 months—1 month longer than those in whom exploration only was done, and 1.3 months less than those in whom gastro-enterostomy was done. The experience of the Mayo Clinic shows that those who had resections had symptoms longer than those who had only gastro-enterostomy or exploration. Evidently there is something in the type of growth, in addition to the duration of symptoms, which determines its resectability. The average total duration of illness of the patient with cancer of the stomach in this series was from 15 to 16 months, whether no treatment was given or whether gastro-enterostomy or exploratory laparotomy were performed. Patients with resections lived, on the

TABLE 8.—*Relation of Duration of Illness and Mortality to Operation for Cancer of Stomach*

	Resection			Gastro-Enterostomy			Exploration Only			No Treatment
Case Series	Cases	Duration of Illness, Mo.	Mortality, %	Cases	Duration of Illness, Mo.	Mortality, %	Cases	Duration of Illness, Mo.	Mortality, %	Duration of Illness, Mo.
Our series	28	8.1 (before operation)	..	35	9.4 (before operation)	....	29	7.1 (before operation)	....	....
McVicar and Daly	524	10.9 (before operation)	..	203	8.9 (before operation)	....	432	8.2 (before operation)	....	....
Cancer with sudden onset	...	12.0 (total cancer illness)	..	...	12.8 (total cancer illness)	....	...	16.5 (total)	....	....
Cancer with preceding indigestion	...	13.5 (total)	..	...	15.0 (total)	....	...	15.5 (total)	....	15.5
			64			54.3			58.6	

average, two months less. The high mortality from all operations and the similar mortalities for resections, gastro-enterostomy and exploratory laparotomy are noted.

Whether a patient has his stomach resected or not may depend somewhat on the hospital environment into which he falls—surgical skill, opportunities for preoperative and postoperative care, etc. Whether more of these patients might possibly have had gastric resections is not known. Sometimes the operative notes made one wonder whether resections might not have been possible; "freely movable tumor of pylorus; gastro-enterostomy done."

Resection.—To the 28 resections in this series, 35 additional cases were added,[11] making 63 for analysis.

11. The additional cases were collected from Detroit hospitals chiefly before and subsequent to the time of the aforementioned series; also from the University of Michigan Hospital, Ann Arbor, 1926-1927-1928. Dr. Fred A. Coller of the University Hospital permitted us to use the latter cases.

Table 9 shows the anatomic location of these 63 resected growths. Practically all occurred in the distal half of the stomach, the greater number in the pyloric and prepyloric regions. No resections of the proximal portion of the stomach were attempted. As noted previously, this is important practically; the resectable growths are more apt to have easily recognizable symptoms, while the inaccessible ones high up toward the cardia are those which more often start with atypical symptoms difficult to recognize.

Table 10 shows the relation of retention to postoperative death and recovery and to anatomic location (tabulating the cases in which this information was available).

TABLE 9.—*Relation of Anatomic Location of Sixty-Three Resected Gastric Cancers to Postoperative Results*

	Postoperative Results	
	Deaths	Recoveries
Pylorus	8	8
Pyloric and prepyloric	8	7
Antrum	3	3
Midportion	5	3
Distal half	5	2
Lesser curvature	3	8
	32	31

TABLE 10.—*Relation of Retention to Postoperative Death and Recovery, and to Anatomic Location*

	Deaths		Recoveries	
Location	Retention	No Retention	Retention	No Retention
Pylorus	5	0	6	0
Pylorus and antrum	5	2	3	8
Midportion	2	6	0	3
Lesser curvature	2	0	2	4

It is evident that:

1. All pyloric growths were associated with obstruction when they came to operation.

2. Of those labeled pyloric and antral, the obstructive cases showed three times the mortality which the unobstructive did.

3. Growths extending to the midportion of the stomach, though showing little obstruction, nevertheless had a high postoperative mortality, probably due to the extensive and difficult resections necessary for their removal.

4. Growths of the lesser curvature gave rise to less obstruction, and their resection was followed by recovery of the patient in a high percentage of the cases; in this small series, they were the most favorable growths for resection. These develop on the basis of preexisting ulcer more frequently than cancers elsewhere in the stomach.

A palpable mass certainly is no contraindication to radical removal. Thirty-four of 53 charts had a note that an epigastric mass was palpable. In the remainder, this datum was not available. Eleven of twenty-six patients who recovered from resections had a palpable mass.

As few autopsies were done, it was difficult to determine the cause of death in all instances. Roughly, three groups of postoperative complications are usually distinguished: (1) abdominal complications, chiefly leakage or peritonitis; (2) circulatory failures from shock, hemorrhage, acute cardiac dilatation, etc., and (3) pulmonary and other complications.

TABLE 11.—*Causes of Postoperative Death in Sixty Patients Following Partial Gastrectomy for Cancer*

	Detroit		Mayo Clinic			
	Our Series	Additional Cases	1927	1928	Total	Per Cent
Peritonitis	8	6	4	6	24	40.0
Circulatory failure	9	5	3	2	19	31.7
Hemorrhage		2				
Shock		3	2			
Cardiac failure			1	2		
Pulmonary complications	2	3	4	3	12	20.0
Embolism *		1	2	3		
Bronchopneumonia	1	1	2			
Abscess of lung	1	1				
Miscellaneous	0	3	1	1	5	8.3
Atrophy of brain				1		
Parotitis				1		
Superior mesenteric injury		1				
Perforated before operation		1				
Unclassified		1				
Totals	19	17	12*	12*	60	

* 9.2 per cent of total number of gastrectomies for cancer.

Many charts had a specific note as to the probable cause of death. To this was added the information in the postoperative interns' and nurses' notes, a record of the temperature, the pulse record, etc. For example: A patient dying within from 24 to 36 hours with rapidly mounting pulse rate, vomiting blood, but having little pain, was thought to have died of shock or hemorrhage. One dying within the first two weeks showing continued profuse drainage from the wound, or having severe pain in the abdomen, irregular temperature and relatively normal pulse rate until shortly before death was thought to have had leakage from the suture line or peritonitis. Pulmonary complications seemed to group themselves readily in most instances by cough, rapid respirations, expectoration and freedom from postoperative abdominal complaints.

On a basis of this rough clinical interpretation, table 11 represents 60 deaths in which data about postoperative complications were obtained.

For comparison, the causes of death following gastric resection in two years' experience at the Mayo Clinic are included.[12]

Apparently, pulmonary complications account for only about one fifth of the total postoperative mortality. Cardiac failure, hemorrhage and shock account for another third. Many of the so-called shock deaths were probably the result of alkalosis, etc., in patients who had toxemia due to retention. With the exception of a small miscellaneous group, peritonitis accounts for the remaining deaths—40 per cent. Thus, pulmonary complications and genuine myocardial failure excluded, most of the complications were "inherent in the wound itself."[13]

So many of these patients come to operation in an exhausted state, and so many cases of extensive and late cancers are accepted for resection that there is considerable risk because of the lowered resistance of the patient. However, a study of the charts indicates that further improvement in recoveries from operation will come with more careful preoperative preparation (repeated lavage and building up of depleted body fluids), deliberate and careful suturing and accurate hemostasis. With the newer anesthetics (spinal, local, etc.) there is not so much premium on speed in these cases, and it seems that immediate postoperative shock was more often due to hemorrhage or toxemia from a poor general condition than it was due to failure of the heart per se.

Another point which must be important is the extent of the resection: How wide of the growth is the division of tissue? A few of the patients with resections who recovered seemed to have had a local removal. The lymphatics draining the stomach are numerous, and get outside the scope of operative removal in short order. One reason for the lack of the success that gives rise to professional pessimism about cancer of the stomach—the feeling that even if the patient recovers, he is doomed to a recurrence within a relatively short time—is, perhaps, that many resections are made too close to the growth.

The case to be described seems to illustrate this:

Case S499.—An apparently satisfactory posterior Polya resection of a large prepyloric gastric cancer was done, with good postoperative recovery. After twenty-five months' freedom from the condition, the patient was admitted to another hospital with signs of obstruction at the cardia, from which he died, the clinical diagnosis being inoperable carcinoma.

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12. Personal communication to the authors from Dr. Donald A. Balfour.

13. As stated, this is only a rough interpretation from a study of postoperative records. Dr. Balfour[12] notes that pulmonary complications and peritonitis may both be found as the cause of death. A small local peritonitis, not of itself sufficient to cause death apparently, may be the only observation at autopsy.

The pathologic report from the first institution contained the note: "All of the stomach wall sent us shows diffuse (cancerous) infiltration to the serosa."

The query, in retrospect, is: If the patient died of recurrence at the cardia, would an anterior Polya resection and anastomosis which might have allowed more of the wall of the stomach to be resected have been better insurance against recurrence?

POSSIBILITIES FOR IMPROVEMENT AND CONTROL

It is evident where improvement will come.

1. It is not appreciated that a mild indigestion, starting suddenly in persons of middle age, if unrelieved by only a few weeks' treatment, warrants surgical exploration for so serious a condition as suspected gastric cancer. The concept is so unusual as regards the average consideration these patients get that it must be grasped as a new clinical entity by most physicians before much headway in control will be in evidence.

In this stage, the clinical history of the illness is the all important element. The knowledge that gastric ulcer is not common, the knowledge of the earmarks of cancerous indigestion, the knowledge that in many cases there are no earmarks, the probable error in the clinical confusion of ulcer and cancer are more important than the physical examination, the laboratory data or even the x-ray picture. It is probably not wise to urge people to suspect cancer of the stomach if they have mild indigestion until there is improvement in the clinical recognition of early gastric cancer.

2. Although the diagnosis is based in most instances on the roentgenologic examination, there is a certain element of error that must be appreciated.

3. Though much of the mortality from gastric resections is due to the weakened state of the patients, improvement will probably come chiefly from careful preoperative preparation and care in hemostasis and suturing.

SUMMARY AND CONCLUSIONS

1. The popular pessimism concerning cancer of the stomach is well founded. Perhaps 3 per cent of the total number of persons who have died from gastric cancer have had the growth resected and recovered from the operation—have had the chance of cure that operative recovery from radical resection represents.

2. Of 287 fatal cancers of the stomach, 24.7 per cent were preceded by long continued indigestion; 75.3 per cent started suddenly from previous good health.

3. Of those which started suddenly from previous good health, 69 per cent started with symptoms which, though mild, were distinctly referable to a pathologic disturbance in the upper part of the abdomen. The chief problem is not the recognition of symptoms, but the arousal of suspicion that they may be of serious import.

4. Cancers that start with atypical symptoms are more apt to be in the left half, the nonresectable portions, of the stomach than toward the pylorus.

5. In the arguments concerning the frequency with which chronic gastric ulcer develops into gastric carcinoma, the fact may be lost sight of that it is not the frequency with which this takes place, but the difficulty of distinguishing clinically gastric ulcer from early carcinoma which is important. One third of the 25 per cent of these patients who had had long continued indigestion had been given the diagnosis "typical ulcer history"; one half of these had been under medical management for ulcer. Ten per cent of the remaining patients whose cancers started from preceding good health were noted as having a history typical of ulcer.

6. Twenty-six per cent of the patients who had not been in hospitals had had roentgen examinations.

7. There is a definite though small error in roentgenologic diagnosis of cancer even when the growth is well developed. With a mildly but definitely suggestive clinical history of a malignant gastric condition, a negative x-ray picture should not entirely rule out cancer.

8. The problem as regards treatment is doing more gastric resections (since the mortality from gastro-enterostomy is high and a successful resection, if at all feasible, is a better palliative procedure than is gastro-enterostomy); and doing them with a lower postoperative mortality.

9. Concerning the deaths following gastric resections for carcinoma, it may be said, in a rough clinical interpretation, that 20 per cent were thought to be due to pulmonary complications; one third were due to circulatory failure, a small number of these cardiac failure per se, the larger proportion shock due to hemorrhage or toxemia from retention and dehydration; and 40 per cent were due to peritonitis.

CHRONIC SUBDURAL HEMATOMA

SUMMARY AND ANALYSIS OF FORTY-TWO CASES COLLECTED FROM THE LITERATURE, WITH REPORT OF TWO ADDITIONAL CASES *

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Prior to the publication of Putnam and Cushing [1] in 1925, great confusion prevailed as to the nomenclature and classification of hemorrhage beneath the envelops of the brain. Hemorrhage beneath the pia, arachnoid and dura and above the dura, as well as into the brain substance itself, was often loosely designated as pachymeningitis hemorrhagica or simply as intracranial hemorrhage. These authors brought order to a division of this chaotic literature by establishing hematomas between the dura and arachnoid as a definite clinical entity. Since their report, numerous studies and case reports have appeared in the literature.

In the treatment for traumatic cases of the head, the prognosis often depends on the recognition of the exact abnormal condition present within the skull. For instance, it makes a great deal of difference in treatment whether there is a cerebral laceration or contusion, diffuse subarachnoid hemorrhage or a clot beneath or above the dura mater. While the symptoms of subdural hematoma have been enumerated in previous contributions, no statistical study of the prominent symptoms associated with this malady has been made. Therefore, I have carefully selected from the literature forty-two confirmed cases of chronic subdural hematoma and have attempted to analyze the signs and symptoms presented by each, in order to consider them collectively and determine the most characteristic features as indicated by their frequency of occurrence. This information is presented in table 1.

ANALYSIS OF CASES

I am aware that the number of cases summarized in table 1 is not sufficiently large to allow one to select the exact observation in the average case of chronic subdural hematoma, yet it is considered better to analyze fewer cases of confirmed lesions than many cases with indefinite lesions and incomplete records. It is believed, however, that

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1. Putnam, Tracy Jackson, and Cushing, Harvey: Chronic Subdural Hematoma, Arch. Surg. **11**:329 (Sept.) 1925.

the statistics arrived at may be taken as characteristic of the condition under consideration and may serve as a guide for further study. The analysis has been made from the point of view of incidence, etiology, symptomatology, morbid anatomy and treatment.

Incidence.—It is interesting to note that in the cases mentioned, as shown in table 2, the incidence is fairly constant after the second decade, while the average age of patients is 39.2 years. Seven per cent occurred in females, while 93 per cent occurred in males. The condition is not rare among children. Schwartz,[2] and also Burhans and Gerstenberger,[3] reported several cases occurring in childhood.

Etiology.—A review of the various predisposing and determining factors will not be considered here. Putnam [1] reviewed the literature thoroughly in this connection and concluded that trauma is the only single antecedent factor common to all cases. In only one case of my collection, that of Rosenbaum, was it definitely stated that trauma had not occurred. No history of any kind was obtainable in two; no mention of trauma was made in two more. Eighty-eight per cent had definite history of trauma, while 98 per cent may well have been traumatic, and only 2 per cent gave a history of no trauma having occurred. Only twenty-five per cent received sufficient injury to produce unconsciousness.

Symptomatology.—There is an extreme variability of symptoms. A picture of the condition usually exists in the rough, but it is seldom that a clearcut, well rounded out picture of an intracranial lesion will develop. The details are sometimes as conspicious by their absence as by their variety.

Dunn [4] defined and described a group of symptoms which he regarded as pathognomonic of the disease. Generally there is a latent period lasting from a few days to several years, then headache followed by psychosis and later coma.

As an aid to the establishment of a definite clinical picture and better recognition of this condition, the frequency of the various signs and symptoms has been determined and a classification of the major and minor symptoms made.

Latent Period: This is the quiet period extending from the time of injury to the onset of symptoms. It was definitely present in 70 per cent of the cases mentioned. Its average length was seventy-six days in thirty-one cases, while only twenty-five days if two of the particularly long cases were excluded.

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2. Schwartz, A. B.: The Etiology of Pachymeningitis Hemorrhagica Interna in Infants, Am. J. Dis. Child. **11**:23 (Jan.) 1916.

3. Burhans, C. W., and Gerstenberger, H. J.: Internal Hemorrhagic Pachymeningitis in Infancy, J. A. M. A. **80**:604 (March 3) 1923.

4. Dunn, A. D.: Pachymeningitis Hemorrhagica Interna, Am. J. M. Sc. **163**:819, 1923.

TABLE 1.—*Analysis of Signs and Symptoms in*

Reported by	Age	Sex	Latent Period	Lucid Interval	First Symptom	Headaches	Mental Changes	Vomiting	Drowsy	Motor	Cranial Nerves	Reflexes	Eyes, Fundi
Cushing[1].....	68	F	3½ hours	..	Headache	Yes	Yes	....	....	Impaired on right side	.....	.....	Left obscure
Putnam[1]													
I.....	18	M	..	..	.....	Yes	Yes	Yes	Yes	Right hand awkward	Weakness of left 6th	Right deep exaggerated; right abdominal absent	3 diopters choking, bilateral
II.....	32	M	5 weeks	..	Headache	Yes (left)	Yes	....	Yes	Right hand weaker than left	Slight anosmia	Knee reflex, right greater than left	1 diopter choking, bilateral
III.....	58	M	10 days	..	Headache	Yes	Yes	....	Restless	Incontinent	.....	Deep reflexes on right side greater than on left	Left disk blurred
IV.....	38	M	2	..	Headache	Yes	Yes	Yes	Yes	.....	.....	Knee reflex absent; others sluggish	Convergent, left; diplopia
V.....	57	M	..	..	Drowsy; headache	Yes (left occipital)	Yes	....	....	Twitching of right arm; motor aphasia; (left-handed)	.....	.....	Papilledema; right pupil larger than left
VI.....	58	M	4 mos.	5 mos.	.....	Yes	Yes	....	....	Paralysis of left arm	.....	Babinski, left	Choking of right; hemorrhage; atrophy
VII.....	46	M	2 weeks	..	Weakness, right leg	Yes	Yes	Yes	Yes	.....	.....	Biceps increased on right; right achilles increased	3 diopters choking, bilateral; vision impaired
VIII.....	34	M	3 mos.	..	Headache	Yes, (occipital)	Yes	Yes	Yes	.....	Diplopia	.....	Bilateral choked disks
IX.....	50	M	8 wks.	10 wks.	Headaches	Yes (right occipital)	Yes	....	Yes	Left arm and leg weak; spasticity, left	Left 7th weak	.....	Papilledema, left pupil larger than right
X.....	34	M	1 year	..	Headaches	Yes	....	....	....	.....	Taste impaired	.....	Left pupil larger than right; bilateral choked disks
2d admission	34	M	..	30 mos.	.....	....	Yes	....	Yes	Left side more spastic than right	.....	Bilateral ankle clonus; left Babinski and Oppenheim	.....
XI.....	20	M	..	..	Rhinorrhea	....	Yes	....	Yes	.....	.....	.....	Old atrophy of disks
Pickens, C. B.: Guy's Hosp. Rep. **78**: 365, 1928	64	M	1 mo.	1 mo.	Headaches	Yes	Yes	Yes	Yes	Right spastic hemiplegia; incontinence	.....	Increased on right side; abdominal absent	Engorgement of veins
West, E. M. B.: Guy's Hosp. Rep. **78**: 474, 1928	49	M	..	..	.....	Yes (occipital)	Yes	....	....	General loss of motor power	3, 4, 6, bilateral weakness; right 5, 7, 9, 12 paresis	Right corneal absent; right abdominal absent; knee reflex, right greater than left	.....
Craig, W. M.: S. Clin. North America **7**: 1523, 1927													
I.....	41	M	1 mo.	..	Drowsy	Yes	Yes	Yes	Yes	Rigidity of right arm greater than left; incontinence	Weakness left 7 and 3 bilateral	Bilateral Babinski	2 diopters choking left; 3 diopters choking right

Positive Laboratory Observations	Temperature	Pulse Rate	Coma	Remission	Injury			Hematoma		Cortex	Blood Pressure	Results
					Type	Region	Objective Symptoms	Region	Consistency			
.....	....	....	Yes	Yes	Fell on floor	Right parietal	.....	Right parietal	Semi-fluid	De-formed	....	Operated on; died
.....	....	50	....	Yes	Foot-ball	.....	.....	Left fronto-parietal	Clot-fluid	Com-pressed	....	Operation; recovery good
Urinary albumin	100.4 (38 C.)	46	....	Yes	Auto accident	.....	Contusion over eye	Left hemi-sphere	Clot-fluid	Flat-tened	....	Ventriculogram; flap; subarachnoid drain; recovered
Urinary albumin; 21,000 white blood cells	102.2 (39 C.)	Slow	....	....	Auto accident	Occipital	Laceration of scalp; unconscious	Left hemi-sphere	Clot	Flat-tened	....	Recovered; exploratory puncture; flap; drain; reelevation and no clot
.....	....	....	....	Yes	Struck with ball	Right parieto-occipital	.....	Right parieto-occipital	Clot-fluid	.....	....	Recovered; ventriculogram; ventricles to right
.....	....	....	Yes	Yes	.....	.....	.....	Bilateral	Fluid-clot	Flat-tened	123/90	Right flap; died
....	....	....	Yes	Yes	Thrown from car	?	?	Right temporo-parietal	Fluid-clot	Com-pressed	100/60	Subtemporal decompression; second operation; died
.....	....	72	....	Yes	Kicked by colt	Left side of head	Uncon-scious	Left parietal	Fluid-clot	Com-pressed	118/70	Ventriculogram; operation; rongeured bone 3 inches in diameter; removed dura; no postoperative exacerbation
.....	....	74	No	Yes	Fell on ice	.....	Uncon-scious	Left temporo-parietal	Clot	De-pressed	116/64	Ventriculogram; flap with decompression; recovery
.....	....	50	Yes	Yes	Struck	Right side of head	Uncon-scious	Right parietal	Clot-fluid	Com-pressed	....	Flap; reelevation; flap and dura removed; drain; recovery
.....	Sub-normal	....	....	Yes	.....	.....	.....	Left temporal	Fluid	.....	110/70	Decompression; home 18 months
,200 hite ood lls	100.04 (37.8 C.)	....	....	Yes	Fell from pier	?	Uncon-scious; lacertation of scalp; depression of frontal	Right frontal	Fluid	Com-pressed	....	Right cyst drain; same day flap re-elevated and patient died
....	....	....	....	Yes	?	Head	.....	Right hemi-sphere	Clot	.....	....	Flap; ventriculogram; recovered
lood rea mg.	Sub-normal	Slow	Yes	Yes	Slipped; struck head	Occiput	.....	Left pos-terior fossa	.....	Com-pressed	140/85	Died; no operation
lood asser-ann sitive	....	96	....	Yes	?	?	?	Right occipito-parietal	Fluid	Flat-tened	105/65	Died; no operation
000 hite ood lls	....	....	Yes	Yes	Struck head on horn	.....	.....	Right temporal	Clots-fluid	Normal	....	Recovered; operation; drained

TABLE 1.—*Analysis of Signs and Symptoms in Forty-Tw*

Reported by	Age	Sex	Latent Period	Lucid Interval	First Symptom	Headaches	Mental Changes	Vomiting	Drowsy	Motor	Cranial Nerves	Reflexes	Eyes, Fundi
Craig, W. M.—Continued													
II	30	M	3 mos.	..	Headaches	Yes, (occipital)	....	Yes	Yes	.....	Diplopia	.....	Bilateral choking of disks with hemorrhage
III	46	M	2 weeks	..	Weakness of right leg and knee	Yes (frontal)	Yes	Yes	....	.....	.....	Right biceps increased; achilles increased, bilateral	Bilateral choked disks with hemorrhage and exudates
IV	14	M	..	..	Headaches	Yes (vertex)	....	....	....	Adiadokokinesia of left forearm; left lower extremity incoordinated	.....	Babinski and Kernig positive, left	1 diopter choking, bilateral with hemorrhage and exudate
V	21	M	3 mos.	..	Dizziness	Yes (right occipital)	Yes	Yes	Yes	Diplopia; residual paralysis of left leg opisthotonos	.....	Achilles bilateral, increased	3 diopters choking, bilateral
Rosenbaum, H. A.: Arch. Pediat. **46**: 58, 1929	9 wks.	M	..	..	Twitching, right side	....	Yes	Yes	Yes	Jerking of right leg and arm	.....	All increased	.....
Grant, F. C.: Ann. Surg. **86**: 485, 1927													
I	52	M	10 days	..	Headaches	Yes	Yes	....	Yes	Weakness of right extremities	Weakness right 7	Reduction of all reflexes	Margins blurred, bilateral
II	67	F	..	..	Headaches	Yes (occipital)	Yes	Yes	Yes	Weakness of right extremities	Weakness right 7	Plantar reduced on right, increased on left; Babinski left	.....
III	43	M	..	..	Buzzing in ears and dizziness	Yes	Yes	....	Yes	Twitching of right side of face and right arm	Right 7 weak	All exaggerated; bilateral Babinski	Vessels full and tortuous
Bondurant, E. D.: Alienist & Neurol. **14**: 1, 1893	41	M	..	..	Drowsy	....	Yes	....	Yes	Left hemiplegia (incomplete)	Right 7 incomplete	.....	.....
Griswold and Jelsma: Arch. Surg. **15**: 45, 1927													
I	46	M	8 days	8 wks.	Headaches	Yes	Yes	....	Yes	.....	.....	Increased right upper extremity; knee reflexes exaggerated bilaterally	.....
II	68	F	4 days	9 days	Despondent	....	Yes	....	Yes	Contractures of toes, right	Lower left 7 weak; left 12 weak	Patellar increased on left	.....
III	54	M	32 days	2 mo.	Headaches; weakness	Yes	Yes	Yes	Yes	.....	.....	Abdominal absent; all increased on right side	.....

Cases of Chronic Subdural Hematoma.—Continued

Positive Laboratory Observations	Temperature	Pulse Rate	Coma	Remission	Injury			Hematoma		Cortex	Blood Pressure	Results
					Type	Region	Objective Symptoms	Region	Consistency			
.....	....	....	....	Yes	Fell on ice	?	Unconscious	Left parietal	.....	.....	....	Recovered; operation
.....	....	72	....	....	Kicked by colt	Left side	Unconscious	Right parietal	Clot-fluid	.....	118/70	Recovered
.....	....	Slow	....	Yes	Wrestling	.....	.....	Right parietal	Clot-fluid	.....	....	No operation; died
.....	....	....	....	Yes	Struck floor	Occipital	Unconscious	Right temporo-parietal	Clot	Medullary hernia	....	Died; no operation; medullary herniation
.....	101	....	....	Yes	No injury	.....	.....	Right and left parietal	Fluid	.....	....	Subdural puncture; recovery
.....	Subnormal	....	Semi-coma	....	Fell down stairs	.....	Fractured clavicle	Left temporo-parietal	Clot and fluid	Compressed; yellowish green	130/80	Flap; recovered; no drain
..rinary ..lbumin	....	60	Yes	....	Fell from ladder	Left occipital	Laceration of scalp	Left temporo-parieto-occipital	Clot-fluid	Flattened; anemic	120/70	Recovered
..ll ..ous	....	Normal	Slow	Yes	Yes	Bathing in heavy sea	.....	?	Left temporo-parietal	Clot	Flattened; anemic	....	Trephine; bone flap
...	....	....	....	Yes	Yes	Maniac	?	.....	Right and left	Clot	.....	....	Died; no operation
....	....	Normal	90	Yes	Yes	Auto struck patient	Left frontal	Not unconscious; left frontal laceration	Left hemisphere	Clot	Normal	120/80	Died; no operation
....	....	99.4	105	Yes	Yes	Fell	Left frontal	Hematoma in left frontal region	Right temporo-parietal	Clot-liquid	Yellow tinged	180/105	Died; no operation
.....	....	98.6	....	Yes	Yes	Struck head against door	Left frontal	Unconscious	Left hemisphere	Clot	Flattened and discolored	170/90	Died; no operation

TABLE 1.—*Analysis of Signs and Symptoms in Forty-Two*

Reported by	Age	Sex	Latent Period	Lucid Interval	First Symptom	Headaches	Mental Changes	Vomiting	Drowsy	Motor	Cranial Nerves	Reflexes	Eyes, Fundi
Griswold and Jelsma—Continued													
IV	40	M	..	..	Headaches	Yes	Yes	....	Yes	Weakness of right side; left arm twitched	Left 7, supranuclear; left 12 weakness	Tendon reflexes hyperactive; Babinski, Oppenheim and ankle clonus, right, positive	.....
V	..	M	..	..	.....	Yes	Yes	....	Yes	Both upper extremities flaccid	Right pupil contracted and fixed; left dilated and fixed	Knee reflexes and biceps absent bilaterally; Babinski positive, bilateral	Hemorrhage, left
Bowen, W. H.: Guy's Hosp. Rep. vol. 59, p. 4													
I	24	M	1 day	..	Headaches	Yes (frontal and occipital)	Yes	....	Yes	Intermittent paralysis of right arm with rigidity; aphasia	Blind	.....	.....
II	62	M	..	14 days	Right pupil dilated	....	Yes	....	Yes	.....	.....	.....	Right pupil dilated
III	56	M	1 day	..	Paralysis of left arm and leg	....	....	....	....	Paralysis left extremity	.....	.....	.....
IV	23	M	6	..	Convulsions	Yes	....	....	....	Convulsions; left arm weak	.....	.....	.....
X	..	M	16 days	..	Headaches	Yes	Yes	....	Yes	Slight spastic paresis, right extremity; aphasia	.....	.....	.....
XII	18	M	11 days	..	Headaches	Yes	Yes	....	Yes	.....	.....	.....	.....
XVI	16	M	11 days	12 days	Drowsy	Yes	Yes	....	Yes	Twitching upper extremity; aphasia	.....	.....	Right pupil dilated
XXI	23	M	Fortnite	3 wks.	Headaches	Yes	Yes	....	Yes	Weakness right arm and leg; convulsions	.....	.....	Pupils dilated
XXII	53	M	7 wks.	..	Dragging of right foot	....	....	....	....	Weakness right side of body	.....	.....	Bilateral papilledema
XXIII	21	M	1 week	..	Fever and unconsciousness	Yes	Yes	Yes	Yes	Aphasia and paraphasia; partial paralysis	Weakness right 7 and 12	.....	.....
XXIV	60	M	3 days	22	Headaches	Yes	....	Yes	Yes	Paralysis right arm and leg; weakness on left	.....	.....	.....
Henschen, K.: Arch. f. klin. Chir. 99 : 67, 1912													
I	2	M	9 days	..	Convulsions, left	....	....	....	....	Clonic convulsions left; right extremities dorsiflexed	Left 6, right 3 weak	.....	Right pupil larger than left; both dilated and fixed
II	29	M	15 days	16 days	Convulsions	....	Yes	....	Yes	.....	Left 6, right 3 weak	.....	Right pupil larger than left
Kasemeyer, E.: Post-traumatische pachymeningitis	..	M	3 yrs.	7 yrs.	Weakness	Yes	Yes	....	Yes	Right side convulsions; aphasia	.....	Abdominal changeable	Vision blurred

ases of Chronic Subdural Hematoma.—Continued

Positive Laboratory Observations	Temperature	Pulse Rate	Coma	Remission	Injury			Hematoma		Cortex	Blood Pressure	Results
					Type	Region	Objective Symptoms	Region	Consistency			
.....	98.6	....	Yes	Yes	Not known	.....	.....	Entire left hemisphere	Clot	Flattened	....	Died; no operation
.....	Normal	....	....	Yes	Unknown	?	?	Left hemisphere	Clot	Depressed	....	Died; no operation
.....	99	76	....	Yes	Struck by engine	Occiput	Unconscious; 3 scalp wounds, 2 in vertex, laceration	Left parietal	Clot and fluid	.....	....	Complete recovery; operation; no drain
.....	99	Normal	Yes	Yes	Struck right side of head against stone	Right side	Right temporal laceration; unconscious	Right temporal	Clot-fluid	?	....	Operation; died
.....	99.2	80	....	....	Fell; struck head	Occiput	Scalp laceration	Precentral and frontal, right	Clot	Depressed	....	Died; found more clot at autopsy
rinary albumin	102	100	....	Yes	Fell down stairs	?	Laceration of scalp	Right parietal	Fluid	Normal	....	Operation; recovery
.....	100	92	....	....	Struck by brick	Head ?	Dazed	.....	Clot	Normal	....	Recovered; drain
.....	....	....	....	....	Fighting	Head	None	Right hemisphere	Fluid-clot	Depressed	....	Died; no operation
rine, bumin	101.6	....	Yes	Yes	Fell on curbstone	Left occiput	Laceration of scalp	Right hemisphere	Fluid-clot	.....	....	Died; no operation
rine, bumin	105	120	Yes	Yes	Struck on head	Left temporal	Laceration, left temporal	Left temporal	Fluid-clot	.....	....	Recovered; operation
....	....	70	....	Yes	Struck by brick	Lest side of forehead	Laceration of left side of forehead	Left parietal	Clot-fluid	.....	....	Recovered; operation; horse hair drain
....	101	Slow	Yes	Yes	Fell	?	None	Left hemisphere	Clot-fluid	.....	....	Recovered; operation; horse hair drain
....	98.6	70	Yes	Yes	Struck by falling ladder	Right temporal	Contusion of scalp	?	Clot-bloody fluid	.....	....	Recovered; operation
....	99	180	....	Yes	Fell from table	Occiput	Unconscious; tenderness	Right hemisphere	Fluid	.....	....	Trephined; gauze pack; recovery
....	98	....	Yes	....	Fell from ladder	Right temporal	Convulsions	Right parietal	Fluid	.....	....	Trephined; gauze pack; recoverey
....	....	....	....	Yes	Fell and struck head	.....	.....	Right temporo-parietal	Clot	.....	....	No operation; died; necropsy

Lucid Interval: The lucid interval is the entire period between the injury and the onset of unconsciousness. Coma was noted in 45 per cent of the cases. The length of the lucid interval could be figured in fifteen cases, the average being 264 days; however, omitting two protracted cases, the average is reduced to 35.3 days. This is ten days longer than the average for the latent period, meaning that ten days was the average length of time elapsing from the onset of symptoms until coma developed. On the other hand, there were seventeen cases in which the patient remained conscious.

Headaches: Headache appears to be one of the most common observations, occurring in 79 per cent. Forty-eight per cent of the total number of patients stated that headache was the first symptom noted. It seems that it occurs in an insidious manner, continually but gradually increasing until some patients are driven almost to desperation just before the psychosis occurs. Seldom is relief secured by drugs, even though the patient may take excessively large quantities.

TABLE 2.—*Age Incidence*

Years	Number of Cases	Percentage
0 to 10	2	4.8
10 to 20	4	9.7
20 to 30	7	17.0
30 to 40	6	14.6
40 to 50	8	19.5
50 to 60	8	19.5
60 to 70	6	14.6

Mental Changes: Mental changes simulating those accompanying lesions of the frontal lobe, occurred in thirty-eight, or 86 per cent. Bowen [5] thought it improbable that subdural hematomas lead to ultimate insanity. Instead he contended that hemorrhages found in the insane are the result of atrophy of the brain associated with mental changes. Robertson [6] likewise did not think hemorrhages to be the cause of insanity; however, instead of being the results of atrophy (as suggested by Bowen), he expressed the belief that they are due to congestion occurring in insane patients. Hemorrhages are more often found in paretic and alcoholic psychopathic patients, and hyperemia of the dura is more frequent in these patients than in others.

Seventy-nine per cent of the patients mentioned complained of drowsiness that deepened into coma in 57.1 per cent.

Motor disturbance was noted in 70 per cent; of these, 29 per cent were spastic, 32 per cent had weakness only, 16 per cent had complete

5. Bowen, W. H.: Traumatic Subdural Hemorrhage, Guy's Hosp. Rep. **59**:4, 1905.

6. Robertson, G. M.: The Formation of Subdural Membranes or Pachymeningitis Hemorrhagica, J. Ment. Sc. **39**:203, 1893.

paralysis, 12 per cent had twitchings and 19 per cent had motor aphasia. Fifty-six presented alteration in reflexes, particularly of the deep group.

The cranial nerves were involved in 47 per cent of the cases. Within this group the olfactory, the fifth, the chorda tympani and the ninth nerves were involved in 5 per cent; the ciliary part of the third in 36 per cent; some of the extra-ocular muscular group in twenty-six per cent; the abducens in 21 per cent; the supranuclear portion of the seventh in 26 per cent, and the infranuclear portion of the seventh in 26 per cent. The seventh nerve was involved in 57 per cent of the cases with disturbance of the cranial nerve. The trochlear was involved in 10 per cent and the hypoglossal nerve in 15 per cent.

Remission of symptoms constitutes the remaining important observation, and occurred in 84 per cent of cases.

There is a difference of opinion as to whether remissions are caused by successive hemorrhages or by the brain compensating for the increased pressure resulting from the clot. These factors may be important if chronic subdural hematoma is attributed to pressure, which is an important factor in many cases, while in many others the intracranial pressure is not increased and in a still larger number it is not equal to that necessary to produce death in other lesions, as in the case of new growths. There may be another factor, perhaps chemical, resulting from the clot, which exerts a lethal effect.

The group of symptoms given constitutes the factors which may be termed major symptoms, while those which follow may be classed as minor symptoms.

Vomiting was noted in 29 per cent, nystagmus in 11 per cent and sensory disturbance in 12.5 per cent. The pulse rate was found to be below 60 in 18.16 per cent and above 100 in 9 per cent. In 13 per cent, the temperature was above 100 F. while in 6 per cent it was subnormal. Irregular respiration was noted late in the course of the disease in 11 per cent of the fatal cases. The opthalmoscopic observations revealed hemorrhages into the retina in 11 per cent of the cases, papilledema or choked disks in 40 per cent and engorgement of vessels alone in 4 per cent. In regard to laboratory observations, 6.81 per cent showed leukocytosis, 13 per cent albumin in the urine and 13 per cent xanthochromic spinal fluid. Roentgen examination revealed fracture in 4.5 per cent of the cases.

Morbid Anatomy.—Hematoma: W. H. Holmes [7] stated that all other intracranial hemorrhage is arterial, but this is venous and results from tearing a small vein which enters the tributaries of the longitudinal sinus. Bowen [5] gave as the probable origin of the blood: (1) the main

7. Holmes, W. H.: Chronic Subdural Hemorrhage, Arch. Neurol. & Psychiat. **20**:162 (July) 1928.

arteries entering the skull, of which he had two cases; (2) meningeal vessels, of which he had two cases; (3) sinuses of the dura, of which he had three cases; (4) vessels of the pia, and (5) cerebral vessels. He considered the pial vessels the most frequent source.

Langer and also Mittenzweig,[8] reported the presence of veins in the parietal region far from the sinuses from which the hemorrhage may occur. In one case[9] of the foregoing group, examination at necropsy seemed to point to the middle meningeal artery as the origin.

In 34 per cent of the foregoing cases the location of the trauma as well as that of the clot was known. Of these, the clot was found on the same side as the trauma in 80 per cent and on the opposite side in 20 per cent.

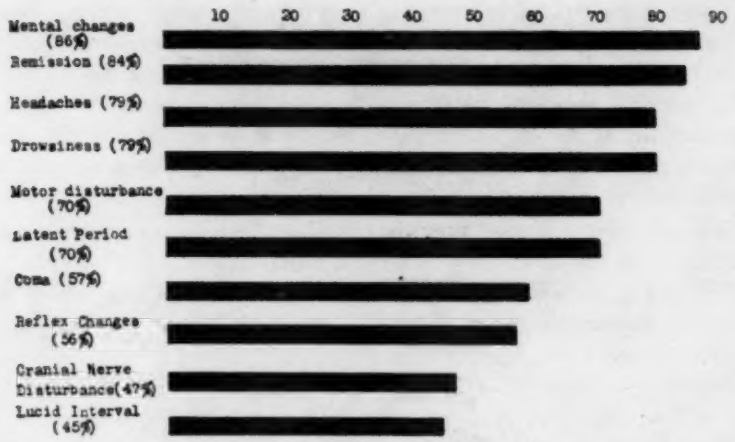

Chart 1.—Incidence of major symptoms expressed in percentages (forty-two cases).

Bile pigment was noted in 69.3 per cent of the hematomas examined. From the high concentration of bilirubin,[9] as previously determined, along with the work of Essick[10] and later that of Weed[11] in regard to the cells of the arachnoid, it may well be said with Rich[12] that the

8. Mittenzweig, quoted by Putnam and Cushing (footnote 1).

9. Griswold, R. A., and Jelsma, F.: The Relationship of Chronic Subdural Hematoma and Pachymeningitis Hemorrhagica Interna, Arch. Surg. **15**:45 (July) 1927.

10. Essick, C. R.: Formation of Macrophages by the Cells Lining the Arachnoid Cavity in Response to the Stimulus of Particulate Matter: Contributions to Embryology, Carnegie Inst. Contrib., Wash. 1920, IX, No. 272, 377-388.

11. Weed, L. H.: The Cells of the Arachnoid, Bull. Johns Hopkins Hosp. **31**:343, 1920.

12. Rich, A. R.: The Formation of Bile Pigment, Physiol. Rev. **5**:182, 1925.

meninges appear to be an exceptionally favorable site for crystallization of a bile pigment within living cells.

The older the case, the more completely the clot will be organized. The likelihood of successive hemorrhages and the importance of this theory have never been established. Lamination of the clot was used as argument for successive hemorrhages, but Putnam [1] stated that Wigglesworth reported lamination of a hematoma formed by a single hemorrhage. It is also known that the clot does not organize evenly throughout. Fifty-four per cent of the hematomas consisted of liquid matter as well as clot, 37 per cent were thoroughly clotted and 13 per cent were practically wholly fluid.

Cerebrum: The intracranial pressure is often increased. Cases have been reported in which the brain was compressed for six weeks

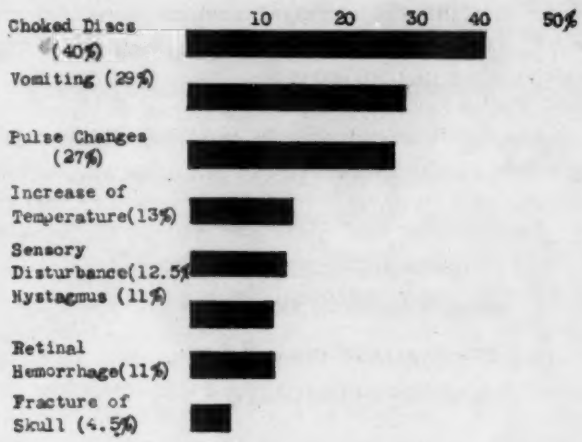

Chart 2.—Incidence of minor symptoms expressed in percentages (forty-two cases).

or more, with perfect recovery. McBurney [13] reported a clot of seven years' duration with the gray matter gone and palsy. Usually the depressed, and often discolored, cortex is not injured grossly or microscopically, regains its normal contour and begins to pulsate shortly after removal of the clot is effected.

Treatment.—Palliative treatment in these cases seems to be of little avail. Massive doses of drugs have been taken for the headaches, with little or no relief. Spinal punctures have been performed, and intraveonus hypertonic solutions have been given, but only temporary remission of symptoms has been secured.

13. McBurney, quoted by Bowen (footnote 5).

The operative results have been most favorable. As soon as the diagnosis has been made, plans for the removal of the clot should be made at once.

Localization of the clot can most often be made by the focal symptoms, and every means should be employed to do so before operation. Bilateral exploration by means of burr holes and dural punctures has been of great value, is less dangerous, is more easily performed, causes less delay and affords more desirable inspection than by ventriculograms. If no information is secured by this means, a ventricular estimation or a ventriculogram may readily be secured through one of the cranial dural punctures already made.

Whether or not an osteoplastic flap or decompression openings should be employed depends on the condition of the patient. The osteoplastic flap seems preferable if more time may be used and the patient is able to stand the increased manipulations. Bernard Sachs and Elsberg [14] raised an osteoplastic flap twenty days after performing a decompression, with incomplete removal of the clot. Putnam [1] reported good results from the simple drainage of fluid, with no attempt to remove the clot. It would seem a good principle to do whatever the patient is able to stand in order to remove as much of the clot as possible. Oozing and bleeding are not marked, so the field can usually be left dry. Drains were used in 17 per cent of the foregoing cases.

Spinal punctures and intravenous injections of dextrose, 50 or 60 per cent, are of value to combat the postoperative edema during the first three or four days.

In this series, 77 per cent of the patients came to operation; 83 per cent of those with operative cases recovered.

ADDITIONAL CASES

CASE 1.—*Traumatic subdural hematoma with onset of symptoms six days after trauma, psychosis, coma. Bilateral burr holes, osteoplastic flap, removal of clot, decompression and recovery.*

B. T., a negro, entered the hospital in a semicomatose state on Sept. 15, 1928. The history as secured from his wife was that he had been drinking freely until the time of injury. Two weeks before admission, the patient returned home intoxicated, with evidence of having received a blow in the occipital region. At this time he also fell against the stove and received an additional injury on the right side of his head. He continued to work as usual until six days later, when he began to complain of pain in the right side of his head with a severe generalized headache. The headache was unrelenting, so the patient sought relief by taking large quantities of a proprietary opiate which he bought at the drug store. About ten days after injury, relatives noted a definite change in his mental

14. Sachs, Bernard; and Elsberg, C.: Extensive Subdural Hematoma After Trauma, New York M. J. **104**:633 (Sept. 30) 1916.

attitude. Three days later (September 13), the patient returned home irrational, and the next morning he was found unconscious in bed. At the time of admission, he was in a semicomatose state; his pulse rate was 44, strong and full; the temperature was 100 F., and respiration was 60. The coma gradually became more profound. The results of a general physical examination were negative. The original site of trauma had healed.

The right pupil was fully dilated. There was slight deviation of the right eye externally; eye movements could not be elicited. The optic fundi were normal. As far as could be ascertained, the other cranial nerves were normal.

There was a spasticity of the left side of the body, including the upper and lower extremities. Twitchings of the left arm were noted. The right side of the body and the extremities were flaccid. (This was interpreted as being natural because of the comatose state.) The deep reflexes were exaggerated on the left side. The abdominal reflexes were absent. There was no ankle clonus, Gordon's sign or Oppenheim's sign.

The laboratory observations were largely negative. The urine was normal. The blood showed: white blood cells, 11,000; polymorphonuclears, 84 per cent. The spinal fluid was xanthochromic and under normal pressure, with 15 cells, 8 lymphocytes and 7 polymorphonuclears. A trace of globulin was found. Cultures of the spinal fluid were negative. The chemical analysis of the blood was negative. Roentgenograms revealed no fracture of the skull.

A diagnosis of "subdural hematoma" was made, and immediate operation was planned. With the patient under local anesthesia, a burr hole was made in each temporoparietal region, and the dura was opened. Nothing was found on the left side.

An osteoplastic flap was turned on the right side. The dura was fairly tense and of a greenish-brown hue. It was opened freely, and a clot covering the entire hemisphere, about 3 to 4 mm. thick in some places, was removed.

A glistening membrane enveloped the clot. It was attached to the dura but not to the arachnoid. The center was of a semiliquid consistency. Before the entire clot had been removed, the patient regained consciousness and talked. The subdural space was lavaged carefully, and all particles of the clot were removed. The brain was only slightly compressed; it pulsated freely. The dura was closed with a gutta percha drain to the arachnoid. (This was removed in forty-eight hours, and little drainage was noted.) A subtemporal decompression was performed, and the flap was replaced.

Section showed a partially organized clot. The outer portion attached to the dura was composed of fibrous tissue. Many well formed capillaries were scattered throughout the layer and large endothelial-lined spaces, some of which contained red blood corpuscles, were side by side beneath the dura. There were many mononuclear leukocytes, with deposits of greenish granules in their cytoplasm. A moderate amount of homogeneous, stained, granular material resembling calcium deposits was found throughout the organized tissue. A single layer of flattened cells on a thin layer of fibrous tissue covered the inner confines of the clot.

Convalescence was uneventful, except for headache on the second and third days. The temperature, which had ranged to 102.4 F. before operation, receded rapidly and remained normal after the third postoperative day. Consciousness and rationality returned while the patient was on the operating table. There were no more twitchings of the left arm, and he was able to use his arms and legs

normally. He left the hospital on the twelfth postoperative day, a little weak, but otherwise well. He returned to the follow-up clinic five weeks later; he had no complaints and nothing abnormal was found. He was working and living his normal life.

This is a typical case of chronic subdural hematoma: the history and the observations before and at operation, as well as the convalescence. It is interesting to note, however, that because of the large amount of the proprietary drug ingested, a provisional diagnosis of "drug poisoning" had been made. The right-sided flaccidity could easily have been interpreted as a paralytic lesion of the left side of the cerebrum. This case bears out the wisdom of Putnam's suggestion of exploratory punctures.

Alcohol may well have been the predisposing cause, but this, aside from trauma, the inciting cause, was the only one present of the many factors mentioned by Bowen.[5] Calcium deposits have been mentioned by others. Its concentration was insufficient to show in the roentgenograms.

CASE 2.—*Subdural hematoma, chronic, onset of symptoms nine days after trauma, psychosis, coma, right subtemporal decompression, removal of clot, recovery.*

R. I., a white woman, aged 50, entered the hospital on March 22, 1929, directly after having been struck by a car. The patient walked but complained mostly of pain in the lumbar region.

The results of a general physical examination at this time were essentially negative except for the blood pressure, 190 systolic and 110 diastolic; tenderness elicited over the lumbar spine, and a hematoma in the occipital region.

The results of the neurologic examination were negative. The spinal fluid was clear and under normal pressure.

A headache of three days' duration and some general weakness were the main factors during the next seven days. At this time the headache reappeared. There were a weakness of the right facial nerve (supranuclear) and ptosis of the right eyelid with diplopia of a transient nature. The optic fundi were normal.

The deep reflexes were hyperactive on the right side. The patient became irrational and gradually more drowsy, until at the time of operation she was in a state of coma. In the meantime, the spinal fluid had become xanthochromic, one pressure reaching 200 mm. of spinal fluid. The leukocytes rose to 10,050. The urine remained normal. Roentgenograms did not reveal a fracture of the skull. The chemical analysis of the blood gave negative results.

A diagnosis of "chronic subdural hematoma" was made, and moderate right subtemporal decompression was performed. Pulsations were absent. The dura was of a greenish-brown hue; it was opened, and a partially organized clot was exposed. In the center was a brownish-red liquid. The tumor covered practically the entire hemisphere. By means of a brain spoon, liberal quantities of physiologic solution of sodium chloride, cotton pledglets and suction, it was entirely removed. The thicker, central mass was removed in large pieces. The

usual smooth membrane covered the clot and was not adherent to the arachnoid. The brain was compressed, but soon pulsated.

The patient rallied on the table. The field was left dry. The dura, as well as the rest of the wound, was closed tightly.

Section showed a fibrous layer immediately attached to the dura. (A portion of the dura was not removed.) Endothelial leukocytes and red blood corpuscles were found in the interspaces. The capillaries were numerous. A number of large, irregular, endothelial-lined spaces containing red blood corpuscles were arranged side by side with only a small fibrous tissue strand interposed between them and the under surface of the dura. Only a few capillaries and fibroblasts extended into the clot proper. The inner surface of the clot was covered with a thin layer of fibrous tissue and a single external endothelial layer.

On the third postoperative day, the patient complained of general bodily pain and headaches. From then on she improved steadily, and was able to sit up on the fifth day. She left the hospital on the twelfth day in good condition. She was seen three months after discharge, and no residual signs or symptoms were found.

In this case the patient had no complaints referable to the head on entrance; however, within seven days a clear picture of subdural hematoma had presented itself. It was possible to follow the case through its entire course, because relatives refused earlier operative intervention. The patient gave a history negative for alcoholism.

SUMMARY AND CONCLUSIONS

1. Chronic subdural hematomas occur more frequently than is generally realized. From the second to the seventh decade, the rate of incidence remained about the same for each ten year period. Several cases have been reported in infants.

2. Trauma is accepted as the determining factor. It is usually of such slight degree as to cause little immediate change.

3. The most important and the most constant clinical observations are: latent period, lucid interval, headaches, mental changes, drowsiness, motor disturbances, change in reflexes, disturbances of the cranial nerve, remission of symptoms and coma. The mean average occurrence of these factors is 67 per cent.

4. A group of minor factors is: vomiting, nystagmus, sensory disturbance, variation in temperature, pulse and respiration, abnormal fundi, xanthochromic spinal fluid and leukocytosis. The mean average occurrence of these factors is 19.7 per cent.

5. The hematoma is not completely organized, is attached to the dura and is enveloped by a membrane composed of fibrous tissue with a mesothelial covering. Clot occurred on the side of the injury in 80 per cent of the cases.

6. Operative treatment gives the best results; 83 per cent of the patients on whom operations were performed recovered.

7. Complete removal of the clot through the osteoplastic flap is the operation of choice, if the condition of the patient will permit, and accompanying decompression is of value.

8. Bilateral burr holes and subdural exploration are advisable in all cases, and would seem preferable to ventriculograms.

9. Dextrose, from 50 to 60 per cent given intravenously, and spinal punctures are usually sufficient to take care of the postoperative congestion and edema.

10. Drains are seldom necessary in these cases.

TUMORS OF THE GIANT CELL GROUP

A PATHOLOGIC ENTITY *

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An outstanding characteristic of all neoplasms is their tendency to reproduce to a limited extent the design and function of the parent tissue, emphasizing the importance of histogenesis in the interpretation of their pathology. In tumors of the giant cell group, attention on the pathologic side has been directed usually to only the histologic appearances of these lesions, and because of this shortcoming, much confusion has arisen in classifying these growths, the microscopic resemblance of some of these tumors to granulation tissue having led to a seemingly endless debate regarding their inflammatory or neoplastic nature. In the studies summarized in this article, attention has been directed to the histogenic rather than to the histologic aspects of these lesions, and by an analysis which traces the origin of these tumors to embryonic functions, a fundamental pathologic relationship has been established between various forms of giant cell tumors heretofore considered under separate headings and as individual entities.

In the following pages, a pathologic relationship between the former clinical entities of the bone cyst, the giant cell tumor in the long bones and the skull, the epulis of the alveolar border and giant cell tumors of the xanthoma group found in the tendon sheaths is unfolded. The conclusions presented are from an analysis of over 400 cases,[1] and are supported by data in regard to the age incidence, location, histology, clinical course and embryologic relationship of these tumors which are described in this paper.

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1. For a detailed tabulation of these cases see Geschickter, C. F., and Copeland, M. M.: Osteitis Fibrosa and Giant Cell Tumor, Arch. Surg. **19**:169 (Aug.) 1929.

THE BONE CYST

Although the limits of osteitis fibrosa have been widely extended since the time of von Recklinghausen [2] to include a multiplicity of entities, the solitary bone cyst which is a form of osteitis fibrosa found usually in the shaft of the long bones of young adults presents certain uniform characteristics which throw much light on the nature of the pathologic process involved.

Foremost among these characteristics are the clinical features of the age incidence and location of these tumors. In 205 cases of osteitis fibrosa, these expanded and cystic areas of central bone destruction are found, in more than 80 per cent of the cases, to occur in patients under 21 years of age. Furthermore, more than 80 per cent of these lesions are situated in the upper end of three long bones in the region of the metaphysis. These predominant sites are the upper end of the femur, the upper end of the humerus and the upper end of the tibia. In the femur they are in the region of the greater trochanter; in the humerus they are in the region of the greater tuberosity; and in the tibia they are in the region of the tuberosity near the epiphyseal line. The roentgenograms illustrate this point. They show an area of bone destruction in a central location near one end of a long bone, overlaid by a cystic expansion of intact thin cortical bone. At the point in the shaft of the bone thus weakened, a pathologic fracture frequently occurs and with the exception of swelling, such a fracture is the most frequent symptom of onset. Clinical follow-ups show that these lesions are always benign and tend to heal after fracture. The average duration of symptoms is two and a half years, and no patient has ever died from the direct cause of the disease.

The occurrence of these lesions in young patients and near the epiphyseal line leads naturally to the conclusion that they are associated with an area of new bone formation; for we know that ossification is not complete in these regions in which bone cysts are most frequent at the time of life at which they occur.

When these lesions are examined pathologically, however, we are confronted with unexpected results. Instead of the area of newly formed bone proceeding from cartilage which we would expect to find in this metaphyseal location and at this age, an evacuated cavity, generally partially filled with serous fluid, is found. There is no remnant left in many cases of bone newly formed from cartilage, but instead there is a shell surrounding the cavity, of fibrous tissue overlaid by new bone formation of a different character. The fibrous tissue is rich in

2. Von Recklinghausen: Die Fibrose oder deformierende Ostitis die Osteomalacie und die osteoplastiche Carcinose, Festschr. z. Rudolf Virchow, 1891.

intercellular material, and at many points the fibroblasts are being transformed into osteoblasts which are laying down new bone directly and not via the cartilaginous route. Our studies of this tissue lead to the conclusion that this tissue of fibroblasts and new bone is not an inflammatory reaction as is currently believed, but an extension of the function of the subperiosteal type of new bone formation and represents a healing reaction.

This conclusion is borne out by the work of Macewen,[3] who in his experiments on the growth of bone inside of glass tubes produced a type of ossification from fibrous tissue identical with the areas of new bone seen in sections of osteitis fibrosa (fig. 4 *B, Arch. Surg.* **19**:185 [Aug.] 1929). The microscopic appearance of the tissue which shows essentially a proliferation of young fibroblasts and osteoblasts resembles more a repair process than inflammation. This repair process is nonspecific and occurs in bone about many different types of bone destroying lesions. It occurs not only in the wall of a bone cyst but also about foreign bodies in the bone, abscesses in the medullary cavity, giant cell tumors, secondary metastatic tumors of the bone and even about primary bone sarcoma.

Pathologically, therefore, osteitis fibrosa is not an entity but a healing reaction around an area of bone destruction. The solitary bone cyst under discussion shows such an area of bone destruction in the form of an enclosed cavity, and about it is the typical healing reaction which we believe is best termed fibrostosis (indicating new bone formed directly from fibroblasts). Clinically and pathologically, it would seem that the bone destructive process often progresses without noteworthy symptoms, for when we recognize the condition clinically, and make the diagnosis or explore, the bone destructive phase is practically always complete and nothing is encountered but the healing phase. This fibroid process of repair sometimes extends over a period as long as forty-five years, and then a latent bone cyst is recognized. The persistence of this healing reaction is due to nature's difficulty in collapsing a cavity with rigid walls and when fracture or a crushing procedure at operation aids in collapsing this cavity, the lesion heals.

Histologic Variants of the Bone Cyst.—The question arises as to what is the original bone destructive process in the bone cyst. In the average case the lesion is of about two and one-half years' duration when first observed, and at the end of such a period, the process responsible for the area of bone destruction has disappeared. When bone cysts are grouped according to the duration of symptoms, however, and the group

3. Macewen, W.: The Growth of Bone, Glasgow, James Macelhose and Sons, 1912.

in which the symptoms average six months are examined, we are able to discover by pathologic examination the nature of the process which forms this cavity in the bone. The x-ray picture in this group of early cases shows a metaphyseal location and a polycystic structure. Forty-six cases of the series of 205 bone cysts were in this group. Microscopically, they were all classed as giant cell variants of osteitis fibrosa. By this is meant that areas of large multinucleated giant cells embedded in a stroma of round cells (tissue typical of a giant cell tumor) were always found in early cases of bone cyst examined pathologically.

In other words, we are inclined to the belief that the bone destructive phase of osteitis fibrosa is characterized by typical giant cell tumor tissue. More broadly stated, the average solitary bone cyst in the long bones is a healed or healing giant cell tumor. Not only do forty-six early cases of 205 cases of osteitis fibrosa show marked giant cell areas, but sixty cases of giant cell tumor of a series of 226 cases show a healing change toward osteitis fibrosa, most marked at the margins of the tumor, but also infiltrating toward the center.

This does not mean that all bone cysts are healed giant cell tumors, nor is it true by any means that giant cell tumors will all progress toward a healed state of osteitis fibrosa. In bone cysts 2 per cent of the cases can be shown to have a bone destructive phase due to a foreign body or an abscess, and in about 20 per cent of the cases rather loosely classed as osteitis fibrosa, some primary disease, such as osteomalacia, Paget's osteitis deformans, fragilitis ossium or osteo-arthritis is responsible for this cyst formation. The majority of solitary bone cysts (78 per cent), however, show their relationship to a preceding giant cell tumor phase by the persistence of giant cell areas which are most frequent in the younger cysts with a shorter duration of symptoms. This is particularly true of so-called polycystic osteitis fibrosa, which in addition to many areas of giant cells indicates the origin of the large solitary cyst by demonstrating the mode of fusion of smaller cavities embedded in giant cell tissue. This relationship is also evidenced by the fact that the bone cyst arises on the metaphyseal side of the epiphyseal line, bordering on the epiphysis where all giant cell tumors occur, and by the fact that the typical giant cell tumor in the epiphysis shows the same healing reaction of fibro-ostosis or osteitis fibrosa at its margin, although to a less marked degree.

The next question to arise is why the giant cell tumor in the epiphysis fails to heal and is a progressive lesion, whereas the bone cyst which arises close to the same region presents a predominately healing reaction. The explanation lies in the difference between the anatomic structure of the epiphysis and the metaphysis. Both have areas of new bone formation derived from cartilage, and both exhibit a bone destructive tumor characterized by giant cell areas. But the epiphysis lacks the defensive

mechanism represented by the thick cortex of the metaphysis and diaphysis of the long bones, and the overlying periosteum which, as Macewen [3] has pointed out, is equipped in the shaft and the metaphysis with a rich and vascular osteogenic layer, not found in the epiphysis after the age of 3. Hence, the giant cell tumor progresses in the epiphysis, whereas this bone destructive lesion on the shaft side of the epiphyseal line is reacted to effectively by the cortical bone of the metaphysis and as the bone grows, the tumor area is pushed toward the region of the midshaft within the protective confines of the thick cortical bone as a walled-off cavity.

NATURE OF THE GIANT CELL TUMOR

The conclusion that the usual bone cyst is an arrested giant cell tumor carries us into the study of the nature of the giant cell tumor in a quest for the origin and etiology of this lesion. The typical giant cell tumor shows an area of bone destruction occurring in the epiphysis of a long bone, and overlying this area there is a thin shell of bone which in many instances is perforated. In our series of 226 cases the average age of the patient is about a decade beyond the average age for the bone cyst. The lesion may occur at any age, but most frequently the patient is in the decade of life between the twentieth and thirtieth years. The age incidence of giant cell tumor when contrasted with that of osteitis fibrosa emphasizes that the difference between these lesions is essentially a difference in the degree of healing, rather than in pathologic nature. The age curves of these growths (fig. 31, *Arch. Surg.* **19:** 220 [Aug.] 1929) show that as the healing power of the bone cell declines with the advance in the age of the patient, bone cysts decrease in frequency while giant cell tumors increase.

The uniformity with which the giant cell tumor occurs in the epiphysis, and the fact that new bone formation occurs here until late in life leads to the conclusion that the pathologic process involved is associated with the formation of new bone from cartilage taking place in this region. Pathologic examination of these lesions confirms this conclusion, for microscopically cellular elements characteristic of a phase in the ossification of cartilage are found.

The tissue of giant cell tumor is rich in giant cells which contain from 15 to 300 nuclei. These large cells are embedded in a cellular stroma containing many round cells the nuclei of which resemble the nuclei of the giant cell. In the cellular stroma occasional spindle cells are found and also small blood vessels, and frequently fresh hemorrhage. The round cells of the stroma seem to be related to the giant cells. The spindle cells are related to areas of osteitis fibrosa and the hemorrhagic areas to strands of newly formed capillaries.

The vascular and cellular stroma seen in giant cell tumor resembles the tissue seen when the marrow cavity is being formed in the embryo. The giant cells that predominate the microscopic picture resemble the large osteoclasts which are associated with the resorption of calcified cartilage that takes place in the histogenesis of bone derived from cartilage. Embryologic studies carried out to determine this point have led to the conclusion that the giant cell tissue observed in giant cell tumors corresponds in nature and structure with a normal phase in the substitution of calcified cartilage by permanent bone.

The Rôle of the Giant Cell in the Histogenesis of Bone.—In the embryo, the long bones are preformed in cartilage, and ossification begins in the center of the shaft and works its way toward the epiphysis, leaving the metaphysis and the epiphysis (the latter with a separate center of ossification) to be ossified in later life. The cartilage cells initiate the bone formation by laying down an increased matrix which becomes calcified; they then atrophy within the small calcified chambers known as the primary areolae. The giant cells appear on the scene after this temporary calcified structure has been laid down. They travel inwardly toward the calcified shaft from the primitive periosteum and penetrate the small rim of subperiosteal osteoid tissue to gain entrance to the central calcified area. In their wake they carry new blood vessels and primitive osteoblasts, and once inside of the calcified central area, destroy it, creating the medullary cavity.

This penetrating rôle of the giant cell, in the embryo, which provides for vascularization and the resorption of temporary bone, we believe is duplicated in giant cell tumor.

Giant Cell Tumors of the Skull.—If the view is correct that the giant cell tumor preserves its embryonic bone-destroying functions, and this tumor is fundamentally related to the proliferation of osteoclasts in bone newly formed from cartilage, then a study of giant cell tumors of the head should furnish valuable evidence in confirmation of this view. For we know that a large part of the bones of the skull and face are formed from membrane, and therefore, the typical giant cell tumors that occur in the head should not arise in these bones, but only in those derived from cartilage. Twenty-two giant cell tumors of the head were examined in an endeavor to prove or disprove the relation of giant cell tumors to cartilaginous bone. Briefly, the results were as follows: Two of the lesions were found in the temporal fossa; fourteen were found in the lower jaw, and six were found in the upper jaw or maxilla. A study of the clinical history and x-ray pictures showed that the two lesions in the temporal fossa arose from those portions of the sphenoid bone derived from cartilage. The fourteen lesions of the mandible could be accurately located in twelve cases.

Nine of these were in the region between the symphysis and mental foramen, just at that point where Meckel's cartilage aids in the formation of the lower jaw, and the other three lesions were in the ramus at the site of another cartilaginous center of ossification. Some difficulty was encountered in establishing the origin of central giant cell tumors of the upper jaw. The maxilla is formed from membrane, but the six lesions in this bone showed a unique tendency to present always into the antrum or the orbit, and when carefully traced, it was found that the ethmoid bone, which is formed from cartilage, and which borders on both the antrum and the orbit, was responsible for the origin of these tumors.

Epulis.—A study of giant cell tumors of the head has confirmed the view that these tumors are related to the process of new bone formation proceeding via cartilage. Another form of giant cell tumor which occurs on the alveolar border of the upper and lower jaws must now be considered from this standpoint. The lesions in this locality have been known for centuries under the name of epulis, and this appellation which means "upon the gums" has been responsible for the inclusion of a multitude of miscellaneous and extraneous entities under this category. When a careful analysis is made, it is possible to split off from this collection a clinical entity composed of a giant cell and a fibroid type of epulis. Histologically, the giant cell epulis resembles the giant cell tumor, and the fibroid epulis resembles osteitis fibrosa, once more illustrating the relationship of these two lesions, the one a destructive phase, the other a predominantly healing reaction. It is to be inferred, therefore, that the epulides are homologous lesions to the giant cell tumor and the bone cyst, and we must explain how these lesions arise independently of a cartilaginous center of ossification. For Bloodgood [4] has shown that these tumors are derived from the alveolar dental periosteum, and this periosteum along the borders of the upper and lower jaws rests on membranous bone and not on bone derived from cartilage. Apparently, these lesions constitute an exception to the general rule just formulated, but the matter must be considered in more detail.

Clinically, the type of epulis under consideration occurs in young people, mostly between the ages of 6 and 30. In our series of cases, we have never found this type of epulis in a patient under 5½ years, nor in a patient over 43 years. Another unique observation in our series of cases (and borne out by 178 cases collected by Scudder [5]) was the fact that the typical epulis rarely occurs at the site of the last molars. Once again the age incidence and location of the lesion give

4. Bloodgood, J. C.: Epulis, Am. Pract. Surg. **6**:818, 1909.

5. Scudder, C. L.: Tumors of the Jaw, Philadelphia, W. B. Saunders Company, 1912.

the clue to the pathology. These molar teeth, where the epulis does not arise, are permanent and not deciduous teeth, and the age limit on the lower side in which children under 5 are shown not to be subject to epulis, is the period before the shedding of the deciduous teeth. We come to the conclusion, therefore, that the epulides arise in the process of shedding the deciduous teeth. It is interesting and more than suggestive that these deciduous teeth are temporary bony structures just as calcified cartilage in the epiphysis and the metaphysis of the long bones and in the chondrocranium of the skull is a temporary bony structure. The epulis, therefore, is thus related to the process of the resorption of the temporary bony structure of the deciduous teeth. It now remains to be demonstrated whether the giant cells here as elsewhere are osteoclasts active as agents in the resorption of the temporary bone. Histologic studies of the roots of the deciduous teeth at the ages that the milk teeth are being shed show this to be the fact. At this time there is a proliferation of giant cells (in this case odontoclasts) which arise from the periosteum and attack the cementum of the roots of the deciduous teeth and loosen them, preparing the way for the eruption of the permanent teeth.

Giant Cell Tumors of the Xanthoma Group.—Giant cell tumors of tendon sheaths which have been traditionally classed with the so-called xanthoma are with difficulty brought into line with the conception entertained here of the relationship of temporary bone resorption to giant cell tumor.

Fortunately, the records of two giant cell tumors of the patella demonstrated that a sesamoid bone embedded in a tendon may give rise to this type of lesion in soft part structures. A study of other sesamoid bones shows that these small bones, which are derived from cartilage are situated most frequently at the metacarpophalangeal joints of the hands just where giant cell tumors of the tendon sheaths are most commonly found. This coincidence suggests these bones as a source of origin for so-called giant cell tumors of the tendon sheaths, and this is corroborated by histologic studies.

When giant cell tumors of the tendon sheaths are examined microscopically, a variant of the typical giant cell structure is seen, characterized by an unusual amount of pink staining fibroid tissue, enclosing in a network cells of the cartilage type. This fibroid substance on further investigation is identified as the vestige of white fibrocartilage from which the sesamoid bones are derived.

Thus giant cell tumors of the tendon sheaths which have long been erroneously classed under the heading of xanthoma, are in reality tumors of the sesamoid bones. By removing these tumors from the confusion of the so-called xanthomatous lesions, the current "granu-

lation tissue" conception of them is overthrown, and their giant cell structure is related to the resorption of cartilaginous bone. This brings these tumors into line with the conception of giant cell tumor advanced throughout this paper.

Etiology of the Giant Cell Tumor.—It is much easier to discuss the etiology of tumor in terms of so-called etiologic factors than to point out the initial event and a subsequent unbroken chain of histologic consequences. For this reason, the literature abounds with references to the etiologic factors of trauma and hemorrhage in the production of giant cell tumor and bone cysts. Konjetzny,[6] Lubarsch,[7] and Pommer [8] are among those of the German school that have attempted to trace the bone cysts to medullary hemorrhage following trauma. We are in accord with these authors in placing trauma in a primary position in the production of these lesions. An attempt will be made, however, on the ground of the embryologic observations pointed out earlier, to show just how trauma acts histologically in producing the bone cysts and the giant cell tumor.

In our series of 226 cases of giant cell tumor and in others in the literature, trauma was obtained in the history of the patient in between 40 and 50 per cent of the cases. Assuming that in the major portion of the other 50 per cent of the cases there was an overlooked and insignificant trauma, it can be pointed out how the prevalent sites for the lesions of giant cell tumor and bone cysts are related to such injury.

The three main locations of bone cysts are in the metaphysis of the femur in the region of the greater trochanter, in the humerus at the site of the greater tuberosity and in the tibia at the tuberosity. These sites at the hip and at the shoulder receive the brunt of the trauma. The epiphysis in the head of the femur and the head of the humerus are shielded by the acetabulum and the glenoid cavity, and hence escape frequent injury. This is why a bone cyst and not a giant cell tumor arises here, for it is the metaphysis and not the epiphysis that is traumatized and as we have seen, this difference between a metaphyseal and an epiphyseal location constitutes the real distinction between a bone cyst and a giant cell tumor. At the lower end of the radius and at the lower end of the femur, on the other hand it is the epiphysis which is exposed and as a consequence, the giant cell tumor is the resultant lesion rather than a cyst. In the head of the tibia,

6. Konjetzny, G. E.: Die sogenannte "lokalisierte Ostitis fibrosa," Arch. f. klin. Chir. **121**:567, 1922.

7. Lubarsch: Die Bedeutung des Traumas zur Enstehung und Wachstum krankhafter Gewachse, Med. Klin. **41**:1651, 1912.

8. Pommer, G.: Zur Kenntnis der progressiven Hematom und Phlegmasie-veränderungen, Arch. f. Orthop. u. Unfall. Chir. **17**:17, 1919.

both the epiphysis and the metaphysis share alike in exposure to injury, and at this site, both types of lesions are common.

Close examination of these sites which so frequently harbor the lesions under discussion, discloses certain interesting details in regard to the intial form of these growths. In an early giant cell tumor (from two to six months' duration instead of the average of fourteen months) the original seat of the lesion is usually asymmetrical in location and subcortically located at one side of the epiphysis (fig. 59, *Arch. Surg.* **19**: 266 [Aug.] 1929). As the lesion progresses, it extends centrally rather than peripherally, because the cortex is more resistant than the medullary cancellous bone, thus obscuring the early typical subcortical location. When we examine the early bone cysts in the metaphysis of from five to six months' duration, instead of the average duration of two and one-half years, we find that this lesion also has a subcortical location. In other words, both the bone cyst and the giant cell tumor arises at a point just beneath the traumatized area of the cortex.

Referring to the work of Lexer [9] on the blood supply of the bones (fig. 58, *Arch. Surg.* **19**: 265 [Aug.] 1929), it is seen that both the epiphysis and the metaphysis receive their blood supply from anastomoses around the joints which send in arterial branches that penetrate the cortex more or less at right angles, proceeding inwardly after the fashion of the periosteal blood supply in the shaft rather than by a central medullary course, as is characteristic of the nutrient artery. The effect of trauma on the blood supply here is to cut off the arteries proceeding inwardly from a cortical position at the epiphysis or metaphysis producing a subperiosteal hematoma. This interruption deprives the cortical bone in these regions of its nourishment and creates a need for collateral circulation by a medullary route. The result is an increased proliferation of the osteoclasts in the medullary cavity in order to open up channels for the budding capillaries proceeding outward toward the injured area. As we have seen, this is a normal histogenic function of the osteoclasts. But this increased osteoclastic activity in an area in which they are already unusually active in the rôle of new bone construction, occurs just at that time when unnourished cortical bone is undergoing necrosis. An imbalance is thus created between bone destruction by osteoclasts and new bone formation that would normally proceed from the reactive cortex were its circulation intact. The defensive reaction of cortical bone, therefore, is suspended while bone destruction by osteoclasts is at its height. This imbalance results in an unchecked hyperplasia of the osteoclasts and produces a tissue

9. Lexer, E.: Die Enstehung entzündlicher Knockenherde, Arch. f. klin. Chir. **71**:1, 1903.

characteristic of giant cell tumor and the early phase of osteitis fibrosa or bone cysts.

In the metaphysis, the reactive cortical bone which is thick and vascular, is apparently capable after a time of overtaking the osteoclasts. In the epiphysis, however, bone destruction seems to proceed at a faster rate than the thin cortical bone in this region can overtake. The result is an arrested lesion or bone cyst in the metaphysis, and a progressive or unchecked lesion in the epiphysis which is known as the giant cell tumor. Even in the epiphysis, however, the balance can be restored if surgical intervention is made before the bone shell is too extensively destroyed. By removing the osteoclastic tissue by the curet and catuery (and we suggest by aiding nature to collapse the bone cavity remaining) the giant cell tumor will also go on to ultimate healing.

That additional metabolic factors may enter into the production of this imbalance between bone destruction by the proliferation of giant cell osteoclasts, and the formation of reactive cortical bone by a process of fibro-ostosis, is shown by studies made on multiple giant cell tumors and multiple bone cysts. In a series of twenty-one cases analyzed in this group, it was found that the patients were either women past the age of puberty in the osteomalacia period, or boys or girls in the age of juvenile bone diseases. The case studies showed that osteomalacia, syphilis, rickets, fragilitas ossium and other associated skeletal diseases were frequently present, and were contributing factors in the production of these lesions and their extension to several bones. More recently at the Mayo Clinic, Dr. R. M. Wilder (in a case to be reported in *Endocrinology*) has placed at our disposal evidence indicating that disturbances in the calcium and phosphorus metabolism associated with hyperparathyroidism due to an adenoma in the parathyroid glands, may favor the production of multiple giant cell tumors in a female past the age of puberty. We ourselves have confirmed this by observing similar disturbances in the calcium metabolism in a patient with a solitary giant cell tumor of the lower part of the radius arising during the latter half of pregnancy.

Thus histologically, trauma is related to the bone cysts and the giant cell tumor, not as an indefinite etiologic factor but as an initial event in disrupting the cortical blood supply which produces an imbalance between osteoclastic proliferation in the medulla and reactive compact bone in the cortex. In the etiology of these lesions individual variations in collateral circulation as well as the extent of the injury to the cortical bone are important factors. Disturbances in the calcium and phosphorus metabolism must also be considered in the oncology of these growths. It is evident, however, from the study summarized

here that the age of the patient, the site of the injury, the rate and extent of cartilaginous ossification at the end of the bone and the nature of the blood supply in the affected region are the predominante factors in the pathology of bone cysts and giant cell tumors.

When all these factors are considered, it is apparent why both bone cysts and giant cell tumors are rare in comparison to the frequency of trauma. It must be emphasized that to have the lesions clinically an imbalance in two normal repair processes is necessary—an unusual increase of osteoclastic proliferation and a diminution or suspension of new bone formation in an injured cortex. These two processes are always active after injury to bone (fig. 57, *Arch. Surg.* **19:** 263 [Aug.] 1929). Both fibro-osteosis (osteitis fibrosa tissue) and osteoclastic proliferation (giant cell tumor tissue) are to be seen after ordinary fractures and in the healing of a subperiosteal hematoma (Cone [10]). Only when the bone destructive phase of giant cell proliferation is in the ascendency for a significant period do the clinical entities of giant cell tumor or osteitis fibrosa arise. The factors concerned in the ascendency of such giant cell proliferation we may list (by way of summary) in the order of their importance as: 1. A normal histogenic proliferation of giant cells which occurs only in calcified cartilage or the temporary bone of the roots of deciduous teeth. 2. Injury and necrosis of an area of cortical bone overlying an actively ossifying epiphyseal or metaphyseal region. 3. A response on the part of giant cells and capillaries in cancellous bone to the need for collateral circulation. 4. Disturbances in the calcium and phosphorus metabolism inhibiting the normal growth and defensive reaction of cortical bone.

10. Cone, S.: Ossifying Hematoma, J. Bone & Joint Surg. **10**:474, 1928.

FETUS RETENTION FOR TWENTY-SIX MONTHS

REPORT OF A CASE *

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This case is interesting for three reasons: (1) the length of time the bones of the fetus were retained in the uterus; (2) the formation of fistulas between the transverse colon and the fundus, and (3) the method of repair.

REPORT OF CASE

History.—A Kurdish woman, aged 30, was admitted to the temporary field hospital of the American Presbyterian Hospital of Meshed, in Kuchan, Persia, Sept. 29, 1928, on account of a tumor of the abdomen. The patient had been married fifteen years, and had had five children, all of whom had died before the age of 3 (not an unusual happening in Persia). Eight years previously, in her fourth pregnancy, she had a miscarriage at four months. There was no history of venereal disease.

In July, 1926, the patient, then eight months pregnant, with a moving fetus, was frightened by an aeroplane which was dropping bombs near her village, and she stumbled and fell as she ran into the house. There was no immediate pain, but the fetal movements ceased, and three weeks later the woman was uncomfortable, with aching pains, which never resembled labor pains. She had occasional periods of fever, with a foul discharge after the sixth week, which grew more copious. Two months after the cessation of fetal movements, several small pieces of bone were observed in the discharge, and during the following year, she noted pieces of fetal bones in the discharge on several occasions. The bones of the feet and legs were recognized.

This woman had no medical treatment of any kind. Part of the time, she was up and around, doing some of her primitive housework, and part of the time, lying down, depending on the amount of fever and discomfort. Near the end of June, 1928, a small fistula opened in the abdominal wall, 1.5 cm. to the right of the umbilicus. As soon as this developed, the pain in the middle part of the abdomen, which had become rather severe, grew less; the vaginal discharge ceased, and a considerable amount of foul-smelling fluid was discharged from the fistula. A week later, the patient noted some feces and grape seeds passing out of this opening. No fecal matter ever passed out of the vagina, nor had the patient menstruated since the beginning of this last pregnancy. There had been occasional vomiting, but no evidence of intestinal obstruction at any time.

Physical Examination.—The patient walked bent over, owing to abdominal discomfort. She was thin, pale and emaciated, with a temperature of 98.3 F., and a pulse rate of 120, weak but regular. There was a hard tumor of the abdomen, the size of a grapefruit, the top of which was 3 cm. above the umbilicus. The tumor was approximately in the midline, extending a little more to the right than to the left; it was firmly attached to the abdominal wall and tender to

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* From the American Presbyterian Hospital.

touch. One and one-half centimeters to the right of the umbilicus, there was a fecal fistula, nearly 0.5 cm. in diameter, with some irritation of the surrounding skin, due to the constant foul discharge. Vaginal examination showed the cervix to be slightly larger than normal, containing scars of previous lacerations; there was some dilatation, but no discharge. The uterus was not movable, and bimanual examination showed that from the cervix to the top of the tumor, all was one mass.

First Operation.—With the patient under ether anesthesia, a right rectus incision was made, extending from the level of the umbilicus to 6 cm. below. An opening was made directly into the uterus, without opening the peritoneum. The contents of the uterus were then removed and consisted of all of the bones of the fetus, except those of the feet and legs, all in a good state of preservation and lying free in the uterus. Some feces and some grape skins and seeds were also removed; there was no evidence of placenta or membranes. In the posterior wall of the uterus at the level of the umbilicus, and 7 cm. to the right of it, was an opening into the transverse colon, near the hepatic flexure. Fecal matter entered the fundus freely through this opening. On the left posterior wall of the uterus, just below the level of the umbilicus, and 6 cm. to the left of it, there was a second opening into the transverse colon, near the splenic flexure. A saline enema was given and at once appeared through the opening, indicating its nearness to the rectum. There was no connection between these two openings in the transverse colon, except through the uterus.

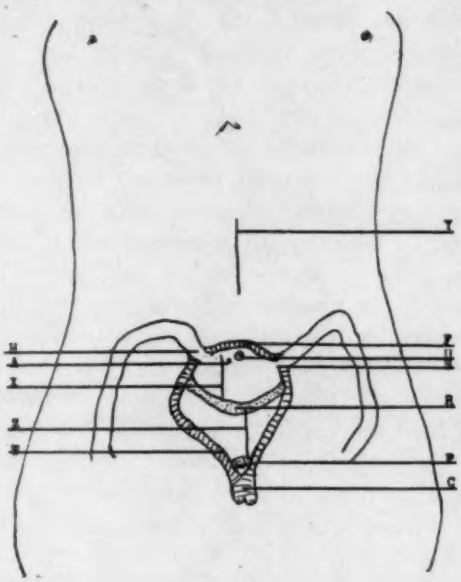
A large catheter was passed from above downward, through the cervix into the vagina, to provide drainage of the uterus from below. A second catheter was inserted into the opening into the splenic flexure, so that the rectum could be washed out from above. A larger tube was inserted into the hepatic flexure so that this colostomy might drain outside. The incision was then sutured around these tubes, the original fistula of the abdominal wall having been first excised. The patient rallied quickly from this brief operation, the only rise of temperature being that to 101.1 F. on the day following.

Second Operation.—As my stay in Kuchan was to be but a few weeks, I operated on the patient again five days later (Oct. 3, 1928) under procaine hydrochloride infiltration anesthesia, a midline incision being made extending upward for 10 cm., from a point 4 cm. above the umbilicus. I hoped to make an anastomosis between the two ends of the transverse colon and do a complete hysterectomy, but on opening the abdomen, I found that the colon, the uterus and the adnexa were all so firmly bound together by old adhesions that such an anastomosis was impossible. This upper abdominal wound was sutured without drainage; there was no elevation of temperature or acceleration of pulse after this exploratory operation.

Third Operation.—The patient being anxious to be cured before the temporary field hospital was closed, I operated again one week later, using procaine hydrochloride infiltration anesthesia, and making a midline incision extending downward for 10 cm. from a point 8 cm. below the umbilicus. The peritoneum was opened below the point at which the fundus was adherent to the abdominal wall. Previous to this the vagina had been thoroughly cleansed and the cervix swabbed with tincture of iodine, while the drainage tubes had been removed, and long tape sponges inserted into the two openings of the transverse colon, and the entire fundus swabbed with tincture of iodine. A partial hysterectomy was done, just above the internal os, which was firmly sutured. The fundus was then sutured from below, and the peritoneum closed without drainage. The great amount of adhesions between the uterus and adnexa and the colon made it impossible to do

an anastomosis of the colon from below. Through the open incision of the first operation, where drainage tubes had been inserted, the gauze plugs were removed, and this original opening of the abdominal wall was tightly sutured in the faint hope that it might possibly heal by first intention even though a steady fecal flow would be passing through this fundus, which had now been converted into part of the intestinal tract. Both the upper and the lower midline incisions healed, but a small fecal fistula developed in the right rectus incision after a few days. The patient had a slight rise of temperature (101.2 F.) on the third day of the operation; except for that, her condition was good.

Course.—Two weeks after this last operation, the field hospital had to be closed and a return made to Meshed; at this time the patient's temperature, pulse and respiration were normal, and she was sitting up in bed, eating well and not



A drawing showing the size and the position of the uterus, the site of the three operations and the method of repair. *H*, opening of transverse colon, near hepatic flexure, into uterus; *A*, fistula from uterus through anterior abdominal wall; *X*, site of first operation; *Z*, site of third operation; *W*, wall of uterus; *Y*, site of second operation; *F*, top of fundus of uterus; *U*, umbilicus; *S*, opening of transverse colon, near splenic flexure, into uterus; *R*, after repair, showing how fundus was made into part of the colonic passage; *P*, after repair, showing where uterus was amputated above internal os; *C*, cervix.

complaining of pain. The fecal fistula was 0.4 cm. in diameter, but most of the feces were passing through the rectum in the proper way. There was no vaginal discharge or bleeding, nor was there any blood issuing through the anus.

Instructions were given to the husband, regarding the cleansing and dressing of the fistula, and the care of the patient, and a supply of sterile gauze was left with him. The last week in November, he came to Meshed and reported to me that there was still a slight watery discharge from the fistula, but no

feces; the patient had returned to her village, where she was walking, although still weak. She had no pain or fever; her bowels moved regularly, and her appetite was fair. The husband was given a small bottle of 90 per cent silver nitrate solution, with instructions to apply a little of this caustic daily to the fistula after cleansing it. Toward the end of January, 1929, the husband again came to Meshed and reported that the fistula had entirely closed, and that the patient was well and doing her housework. I had hoped that the woman would come to Meshed that she might be given a barium enema and some roentgen films be secured, but she has not done so yet.

COMMENT

The history of the woman's fall was sufficient to account for the death of the fetus, but it is more difficult to explain why labor did not start; possibly this was owing to the old scars of the cervix, the result of former lacerations. Both Williams [1] and De Lee [2] mention "missed labors" briefly, and cite the cases of Menzies [3] and Hennig,[4] in which the fetus was retained for 280 and 210 days, respectively, after full term. Many cases are recorded of lithopedions, especially in extrauterine pregnancies, one in China [5] retained three and a half years, and several reported by Masson and Simon,[6] who also give an extensive bibliography. Sourasky [7] reported a simultaneous abdominal and tubal pregnancy with retention of the fetuses for two and a half years, but the longest retention of which I can find record is that reported by McCormick; [8] the fetus was retained in the abdomen for fifty years. In practically all of these cases, mumification had set in. Cases with purulent disintegration, however, are rare. Cohen [9] reported one in which the 4 months old fetal head was carried in the uterus four years. In the case which I report, the majority of the bones of an 8 months old fetus were in the uterus for twenty-six months, with ulceration into the transverse colon in two places and a fistula of the abdominal wall finally developing.

One may assume that the fundus soon became adherent to the anterior abdominal wall and remained fixed there; but it is more difficult to visualize the pathologic changes between the posterior wall of the uterus and the transverse colon, with ulcerations due to the pressure of the

1. Williams, J. W.: Obstetrics, ed. 5, New York, D. Appleton & Company, 1926, p. 164.
2. De Lee, J. W.: Obstetrics, Philadelphia, W. B. Saunders Company, 1913, p. 474.
3. Menzies: Glasgow M. J., July, 1843, p. 229; quoted by De Lee.
4. Hennig: Arch. f. Gynäc. **13**:292, 1878; quoted by Williams.
5. L. M. S. Margaret Hospital for Women: China M. J. **38**:504 (June) 1924.
6. Masson, J. E., and Simon, H. E.: Surg. Gynec. Obst. **46**:500 (April) 1928.
7. Sourasky, M.: Lancet **2**:650 (Sept. 25) 1926.
8. McCormick, E. J.: Ohio State M. J. **22**:501 (June 1) 1926.
9. Cohen, H.: M. J. & Rec. **126**:369 (Sept. 21) 1927.

fetal bones. As this was taking place and part of the transverse colon was being eliminated, why were there not violent symptoms of obstruction and toxemia?

The question may be raised of the possibility of obstruction if the thick wall of the uterus should undergo involution and reduce the size of the passage. It is doubtful whether uterine tissue which has been infected and hypertrophied for such a long time ever regains its tone and becomes contracted. The long retention of the fetal skeleton with the constant state of infection of the uterus and the subsequent formation of fistulas indicate the extent to which nature is able to take care of infection, and the unique methods she will use to get rid of foreign materials that cannot be absorbed. I believe that if surgical intervention had not occurred at this point, gradually all of the fetal bones would have been discharged through this fistula of the abdominal wall.

One might consider whether there is any danger of toxic absorption by the fundus, which is now being used as part of the large colon. Probably the months of infection and irritation have so greatly diminished the absorbability of the walls of the uterus that it merely acts as a mechanical passage. If menstruation should ever recommence, which is extremely doubtful, the fluid will, of course, be readily discharged through the rectum.

SUMMARY

The case reported is that of retention of the skeleton of an 8 months old fetus for a period of more than two years, during which two fistulas were formed between the fundus of the uterus and the transverse colon, and finally a fistula between the uterus and the anterior abdominal wall. The fetal bones were removed, but it was found necessary to do a partial hysterectomy, and the fundus was used to form the passage between the two openings of the transverse colon.

A REVIEW OF UROLOGIC SURGERY*

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KIDNEY

Surgical Technic.—Halbfas-Ney [1] reviewed data on resection of the twelfth rib in many cases during recent years. Reports of this procedure in the literature are meager, and opinions as to its merits are varied. Israel and Albarran seldom used the procedure; Kuster observed it only once, and Wildbolz used it only twice in 175 cases of renal tuberculosis. Kümmell, Frangenheim-Wehner and Israel are of the opinion that incision of the kidney should be extended anteriorly for better exposure. Schmieden resected the twelfth rib twenty-nine times in 92 cases in which nephrectomy was performed; in 1 case the eleventh rib also was taken. The possibility of injuring the pleura has been an objection to this method, but such injury occurred in only 3 cases of Halbfas-Ney's series. He resected the twelfth rib in all cases if the kidneys were high-lying, as well as in those in which the kidney was adherent in the region of the upper pole.

In a series of 203 cases of nephrectomy, the rib was resected in 56 (36 per cent). The surgical indications were tuberculosis in 25 cases (44.6 per cent), tumors in 12 cases (21.4 per cent), pyonephrosis in 15 cases (26.8 per cent), and hydronephrosis in 4 cases (7 per cent).

* Submitted for publication, April 26, 1930.

1. Halbfas-Ney, P.: Die Resektion der letzten Rippe im Dienste der Nierenfreilegung, Ztschr. f. urol. Chir. **27**:275 (May) 1929.

There were also 2 operations of pyelotomy, 1 of nephrostomy, and 2 exposures which were carried out with resection of the rib, making 61 resections. Follow-up records showed that only 46 of the patients were alive. The wounds of these had all healed uneventfully. The region of the resection showed deep retraction. Pain was not felt on deep breathing, and the stump of the resected rib was not painful on pressure. A few patients noted slight anesthesia of the area or a tickling in the scar, as well as light, radiating pain on exertion. Halbfas-Ney expressed the belief that these conditions are due to the paresthesia of the cut nerves and not to resection of the rib.

[ED. NOTE.—It may be necessary in certain cases to resect or fracture the rib. Halbfas-Ney seems to have used this method more frequently than is the common practice. One of the great advantages of the Mayo incision is its possibility of being carried forward. This, together with the division posteriorly of the lateral arcuate ligament, should give adequate exposure in most cases. Should more exposure posteriorly and superiorly be necessary, simple fracture of the twelfth rib may be employed. Resection of the rib is in itself a major operative procedure and should be reserved for those cases in which other methods of exposure have not been satisfactory.]

Hepburn [2] reported a case in which resection of half of a solitary double kidney was performed. He concluded that partial nephrectomy in such cases can be done successfully with marked compensatory improvement in the function of the remaining portion of the kidney. The simplest and safest method of heminephrectomy of the diseased double kidney is to separate the halves by blunt dissection with the finger. The cleavage will be at the point of least resistance, between the terminals of the blood vessels. This avoids the danger of destroying the circulation to the good portion of the kidney and of cutting into calices. A few pressure mattress sutures to control the oozing of blood are all that is necessary to place in the cut end, and it is not essential to cover the raw end with renal capsule.

Walters [3] considered that the most desirable cases for heminephrectomy are those in which there is complete duplication of the renal pelvis and ureter and in which it is necessary to remove only the

2. Hepburn, T. N.: Hemiresection of a Solitary Kidney, Ann. Surg. **90**:402 (Sept.) 1929.

3. Walters, Waltman: Heminephrectomy or Resection of a Part of the Kidney: Report of Four Cases, Surg. Gynec. Obst. **50**:473 (Feb.) 1930.

portion of the kidney involved by the lesions. He reported three cases in which successful resection of the diseased portion of a duplicated kidney was carried out, and also one resection of the lower pole of a kidney containing a large solitary cyst. Success of the operation depends on not opening into the adjacent calix of the remaining portion of the kidney and on the assurance of complete hemostasis at the site of the resection. It is an advantage, after beginning the resection, to place a finger in the dilated calix and pelvis of the portion to be resected, so as to assist in determining its outer limits. It has not seemed necessary during the resection, even temporarily, to interfere with the blood supply to the remaining portion of the kidney. Immediate bleeding from the cut renal parenchyma stops quickly with the placing and tying of mattress sutures over small bits of muscle tissue and approximation of the cut edges of the kidney. A v-shaped resection, when possible, aids in carrying out this procedure. Pieces of muscle are used to prevent the mattress suture from tearing through the parenchyma.

In three of the cases such excellent approximation was obtained that after the mattress sutures were placed, the edges of the fibrous capsule could be approximated with a running suture. In the case in which this was not possible the denuded area of the kidney was covered with a portion of the perirenal fat in the form of a patch. Studies were made preoperatively and postoperatively of the function of each kidney separately, and pyelograms were made of the duplicated kidney. Resection of the diseased portion of the kidney did not interfere with the function of the remaining portion, and in each instance resection was followed by excellent results.

Anomalies.—Thompson [4] noted 19 cases of horseshoe kidney in a review of approximately 13,000 reports of necropsies. Sixteen cases occurred in men and only 3 in women. The condition is much more common in men, thus differing from the sex incidence of solitary kidney. The anomaly was recorded at almost all ages, but the average for men was 35 and for women, 24.

Horseshoe kidneys are situated lower than normal kidneys, on planes extending from below the level of the brim of the pelvis as high as the third lumbar vertebra. The union of the two kidneys may be formed by true renal tissue, at either the upper or the lower pole, the latter occurring more frequently. A fibrous tissue bridge is not recorded in

4. Thompson, A. R.: Horseshoe Kidney, Guy's Hosp. Rep. **79**:201 (April) 1929.

these cases. Horseshoe kidneys are usually heavier than the weight of two normal kidneys.

The ureters passed in front of the mass in 7 cases, and behind the mass in 1 case. The ureters were double, except in 2 cases in which they were single. Horseshoe kidney is rather uncommon; the incidence was 1 in 700 cases coming to necropsy. Renal function was poor in one fourth of the cases. One third of the patients died from some infective process.

Kretschmer [5] reviewed reports in the literature of 30 cases of true supernumerary kidney, 1 of which was his own. It is his belief that this condition is less common than any other congenital renal anomaly. Twenty-one of the cases were observed clinically, and 8 were discovered at necropsy. The largest number of patients were in the second decade of life, which would seem to justify the conclusion that this renal anomaly tends to produce pathologic changes in the kidney early in life. In 17 patients, the left side was affected and in 12, the right; in 1 case the site was not mentioned. In most of the cases the site was given rather accurately, that is, below the so-called normal kidney. Usually in this type of anomaly only 2 ureteral orifices are found in the bladder, which appears normal in the cystogram.

Lesions were present in 19 of the supernumerary kidneys. Stone and infection were the most common. Stones occurred in 3 cases; in 2 cases they were found not only in the supernumerary kidney but in the other kidney on the same side. In another case all 3 kidneys were the seat of stones and severe infection. The supernumerary kidney was normal in 7 cases and in 4 cases the condition was not mentioned. The other kidney on the side affected was normal in 14 cases, and a lesion was not mentioned in 6 cases; thus a lesion was present in 10 cases only. As in the supernumerary kidney, calculus was the most common condition, having been reported in 4 of the 10 cases.

Pain was the most constant symptom, being present in 16 cases. The description, duration and site of the pain varied; it was described as epigastric, abdominal, renal colic and pain in the left side of the abdomen. Palpable abdominal tumor was noted in 14 cases; tumor was not present in 7 cases, and in 9 cases tumor was not mentioned.

McCown [6] described renal ectopia as a condition in which the kidney is congenitally in a faulty position and its blood supply is anomalous.

5. Kretschmer, H. L.: Supernumerary Kidney, Surg. Gynec. Obst. **49**:818 (Dec.) 1929.

6. McCown, P. E.: Bilateral Renal Ectopia, J. Urol. **22**:653 (Dec.) 1929.

This distinguishes ectopic kidneys from low-lying kidneys with the blood supply coming from the proper level of the aorta. Ectopic kidneys are usually smaller than normal. The pelvis is on the front in the pelvic type of kidney and varies with the ascent and degree of rotation in the high positions. In bilateral ectopia, the kidneys may be fused or lie close together in the pelvis; the left is usually slightly lower than the right. The ureters are normal but short, unless abnormality of the bladder exists. Kidneys of this type are likely to be lobulated; their posterior walls are creased by contact with the brim of the bony pelvis or rounded out to fit into the hollow of the sacrum when wholly within the true pelvis. They lie behind the mesosigmoid or the structure of the vicinity into which they encroach. Ectopic kidneys are vascularized from the proximal vessels in the plane in which they lie, those in the pelvis receiving their veins and arteries usually from the common iliac or the common and external iliac veins, whereas those in the false pelvis are vascularized from the lower part of the aorta and vena cava. The misplaced kidneys may function normally, as in McCown's case, for sixty-seven years. The most common lesions are pyelonephritis and hydronephrosis; calculus, sarcoma and tuberculosis have been reported.

The symptoms usually consist of sacro-iliac backache, pain in the lower part of the abdomen radiating frequently to the hips and limbs, and increasing during menstruation.

Pyelitis in ectopic kidney can be cured in about the same ratio as in normally placed kidneys and by the same treatment. In the non-fused cases, nephrectomy may be done; the only difficulty consists in locating and controlling the anomalous blood supply. Pyelotomy may be done in some cases. Nephrotomy is not desirable. Attempts at fixing ectopic kidneys at a higher level have usually failed, because of short ureters and the blood supply.

[ED. NOTE.—The care to be used in distinguishing true renal ectopia from simple nephroptosis, as described by McCown, is important. Operative procedures, such as fixation or suspension, undertaken without recognition of the ectopic blood supply and short ureter, may lead to serious difficulty and perhaps disaster. Likewise the treatment of pathologic conditions such as stone or infection in this type of kidney must be approached with conservatism and with a full knowledge of the anatomic peculiarities of such anomalously placed organs.]

Thompson,[7] in reviewing a series of records of necropsies, found 32 cases of solitary kidney, a proportion of 1 solitary kidney to 400 necropsies. This observation reveals that the condition is much more common than some observers have noted. In the necropsy reports from the London Hospital, the proportion was 1 in 124 cases. There were 15 female and 17 male patients. Patients with this anomaly are not good risks for treatment. Excluding children under 1 year of age, 8 died of an infective process and 2 of renal failure. The average age at death of patients aged more than 1 year was 33 years. In 60 per cent of the cases, solitary kidney was the only congenital defect recorded.

Of the 32 cases, 20 are definitely recorded as of large single kidneys. Thompson expressed the belief that a hypertrophied kidney, although it may appear to be sound, is not a good organ so far as function is concerned. In considering the vascular supply, 1 case is noted in which there was definite segmental arrangement of the arteries.

The right kidney was more frequently absent in the males than in the females, and vice versa in the case of the left kidney. The presence of two ureteral orifices does not necessarily indicate the presence of two kidneys, and cystoscopy previous to an urgent operation may be useless or misleading unless catheterization is carried out. In any question of removal of an injured kidney in emergency, the surgeon may palpate for the presence of the other kidney.

Ptosis.—Thomas[8] stated that it is doubtful whether the potential danger of movable kidney, with its insidious, symptomless destruction of the kidney by progressive hydronephrosis or infection, is always completely acknowledged by the general practitioner. Hinman, in 105 cases of hydronephrosis, reported urologic evidence of nephroptosis in 90. The majority of Thomas' series of 75 patients with nephroptosis exhibited pyuria of some degree; the complication of pyelitis was not recorded unless, by ureteral catheterization and the usual pyelographic evidence, the kidney was proved to be the source. There were 18 cases of pyelitis, 3 of pyelonephritis and 2 of pyonephrosis. Other pathologic complications were hydronephrosis, 19 cases, calculi, 10 cases, and tumor, 1 case. The 75 cases may be divided into (1) simple ptosis, unilateral or bilateral, treated palliatively or operatively; (2) those

7. Thompson, A. R.: Solitary Kidney, Guy's Hosp. Rep. **79**:207 (April) 1929.

8. Thomas, B. A.: Observations on the Diagnosis and Treatment of Movable Kidney, J. Urol. **22**:603 (Dec.) 1929.

associated with hydronephrosis; (3) those associated with pyelitis, pyelonephritis or pyonephrosis; (4) those associated with calculi, and (5) those associated with tumor.

Symptoms, in these cases, dated back from a few hours to forty years. Urinary symptoms and renal or lumbar pains occurred with almost equal frequency in from 80 to 85 per cent of patients, while gastro-intestinal and nervous disturbances were found in only about 20 per cent. To determine the degree or extent of mobility of a kidney accurately, pyelography is essential and must be done with the patient in both the erect and prone positions. Complete reliance should not be placed on characteristic symptoms such as discomfort, dull or severe pain in the renal areas, gastric disturbances, neurosis or the demonstration of a palpable or movable mass in the loin.

In the treatment of nephroptosis, each case should be studied separately to determine the most appropriate and best procedure. The outstanding object must be relief of the subjective symptoms as well as the prevention of the destruction of the kidney by hydronephrosis and infection. Palliative treatment is indicated in mild cases, especially those associated with general visceroptosis, when the subjective symptoms are relieved by rest or abdominal supports. Palliative treatment is contraindicated when any subjective symptoms are not completely relieved by supportive appliances; when the threat of renal injury from urinary retention and infection is uncontrolled by apparatus; when severe pyelitis, pyelonephritis, pyonephrosis, calculus or tumor coexists; when rotation of the kidney, torsion of the pedicle or fixation of a kinked ureter is present; when harmful traction is exerted on other organs, and when the kidney is movable to more than the first degree.

The mortality of nephropexy for nephroptosis is practically nil. Edebohls claimed only 1.65 per cent in 864 cases, and Kelly 0.4 per cent in 245 cases. In Thomas' series there were no deaths. When the disease is allowed to progress to the destruction of the kidney, necessitating nephrectomy for treatment, the prognosis becomes graver. Nephropexy for ptosis in 19 cases of this series has been successful except in 1 case. Failure should never exceed 10 per cent, which represents a large measure of surgical success as compared with the results of palliative treatment. Surgical failures can be ascribed usually to faulty technic in fixation of the kidney, the incomplete removal of fatty tissue between the posterior surface of the kidney and the lumbar muscles to which it is to be fixed, failure thoroughly to mobilize the kidney and ureter and free them from any adjacent adhesions or fascial restrictions, and too short confinement to bed after operation. The

patient should be kept in a recumbent position for about a week, should not lie on the unaffected side for two weeks, may sit up in bed in three weeks and should not be allowed out of bed for four weeks. Vague pains may persist for six months after the operation.

Braasch[9] is of the opinion that too much enthusiasm for fixing floating kidneys may result in unwarranted nephropexy. About twenty-two years ago, during an era of nephropexy, a series of patients with floating kidneys were operated on at the Mayo Clinic. Many of these patients returned two or three years later without improvement in symptoms, or they claimed that the pain had shifted to the other side. On account of these unfavorable results, such operations were discontinued. According to Braasch, there are unquestionably movable kidneys which if fixed would relieve the patient's symptoms. Nephropexy may be indicated when pyelographic evidence demonstrates definite ureteral obstruction with resulting pyelectasis, and when there is permanent acute angulation as the result of nephroptosis, provided all other abdominal lesions have been excluded, the patient is not considered neurotic, and the other kidney is not similarly affected. Often the urogram will show dilatation not only in the renal pelvis, but of the entire ureter, without any evidence of obstruction. In such cases an atonic condition is probably the predominating factor and cannot be relieved by nephropexy. In other cases the pyelographic evidence may show minor changes which make one doubtful as to the existence of obstruction.

Mathé[10] described two types of movable kidney responsible for the definite clinical entity characterized by lumbar pain, loss of weight, and urinary, gastro-intestinal and nervous disturbances, which require surgical fixation. The first group consists of the infected kidney presenting pyelonephritis which, after it has acquired the lower position, has become anchored in place by adhesions to the surrounding structures. In this type of ptosis a supporting belt, instead of elevating the kidney, overrides and irritates it, and fails to give relief. The second type of movable kidney requiring surgical relief is the one in which the kidney, in dropping, causes the ureter to be arrested, compressed or kinked over fibrous bands or an aberrant blood vessel.

Lewis[11] stated that although kidneys have been unnecessarily anchored, there have also been many unnecessary operations of

9. Braasch, W. F., in discussion on Thomas (footnote 8, p. 685).

10. Mathé, C. P., in discussion on Thomas (footnote 8, p. 691).

11. Lewis, Bransford; Crowell, A. J., and Quinby, W. C., in discussion on Thomas (footnote 8, p. 683).

appendectomy. He has observed many cases in which the appendix was removed when the real condition was nephrosis and backward pressure in the ureter.

Crowell [11] has had excellent results following nephropexy, and he does not hesitate to perform it in properly selected cases.

Quinby [11] stated that cases occur in which there is a rather sudden onset of acute renal pain which is undoubtedly due to an abnormally movable kidney. In such cases dilatation of the renal pelvis or ureter cannot be demonstrated, but there will be delayed emptying time of the pelvis. During the last four or five years he has observed from 12 to 17 such patients in whom time has proved that nephropexy effected cure.

Lowsley [12] stated that the indications for operation on nephroptosis are direct and simple. When bilateral nephroptosis is present, operation is contraindicated. This condition is usually associated with enteroptosis, and operation may add to the pain instead of relieving it. There is a certain amount of pull on all the viscera which extends to the attached, suspended kidneys; this increases rather than diminishes the pain. In cases in which one kidney is down, and symptoms of colic and hydronephrosis are associated, if a definite diagnosis has been made, palliative treatment, including belts and irrigation of the renal pelvis, is first attempted. If these measures fail to give relief and the pain referable to the kidney still persists, nephropexy is indicated. Lowsley suspends the kidney in such a manner that he is reasonably sure it will not come down. It is extremely important to keep the patient in bed long enough after the operation so that the tissues may become firmly healed. The minimal time is three weeks and sometimes longer. A long vacation after the operation is desirable.

[Ed. Note.—As pointed out by Braasch, indiscriminate nephropexy as done twenty years ago led the operation into deserved disrepute. Nevertheless, the recent reapplication of the operation in selected cases may not be without clinical merit. Mathé and Lowsley contended that suspension and fixation may gain satisfactory results if meticulous care is taken as to the type of case in which the procedure is applied. As mentioned elsewhere in this review, ectopic kidneys with a concomitant ectopic blood supply and short ureters are unsuitable for renal suspension or fixation. If there is general visceroptosis with bilateral nephroptosis, little can be expected from operation except an aggravation of an already distressing pathologic condition. On the whole, Braasch's conservative attitude is to be recommended. He would reserve surgical fixation for such cases in which there is definite ureteral obstruction with pyelectasis, or in which there is permanent acute angulation of the

12. Lowsley, O. S., in discussion on Thomas (footnote 8, p. 690).

ureter. He also emphasized the fact that other abdominal lesions must be definitely excluded, and that neurosis as a factor must be adequately ruled out before major surgical procedures of this type are undertaken.]

Hydronephrosis.—Von Lichtenberg [13] stated that in cases of double kidneys operation can be performed either on the ureter or on the pelvis of the kidney. In case of bifid ureter, part of the kidney with its respective ureter may be resected. In case of double ureter, one ureter may be implanted either into the pelvis of the kidney or into the other ureter. The ureter of the diseased half of the kidney is the one which is resected and implanted. The essential steps of the operation are described as: (1) careful preparation of the hilus and the ureter; (2) amputation of the ureter at the point of origin, leaving little redundant tissue in order to prevent the formation of a stricture; (3) closure at the point of the amputation; (4) resection of the redundant ureter; (5) implantation into the pelvis of the kidney or end-to-side implantation into the retained ureter above the site of crossing, and (6) drainage by nephrostomy for prevention of tension on the suture line. The double pelvis may be anastomosed either with or without the resection of the extra ureter, and the diseased half of the kidney may then be resected. In cases of double kidney, resection should be done if the extent of pathologic processes permits. The resection usually is bloodless, and the resected half, attached only to the ureter, is drawn out of the operative field. Small bleeding vessels are then ligated. The two leaves of the capsule are brought together so that the line of ablation is completely covered. The free edges of the leaves are placed in the wedge formed by the resection, sewed together, and closely approximated by two or three through-and-through sutures.

In plastic operations for urinary obstruction, the obstruction must be either radically eliminated or circumvented. In disorders such as accessory arteries and kinks, a plastic operation is not necessary. In the remaining cases the relief of the obstruction is associated either with the transverse or the lateral incision of the ureter. Topographically, three types of obstruction are differentiated, depending on the site of the lesion: those at the ureteropelvic juncture, those along the course of the ureter and those in the intramural portion of the ureter and at the opening into the bladder. If a stricture is found to be close to the ureteropelvic juncture, the stricture should be resected and the ureter implanted into the pelvis.

Von Lichtenberg implants the ureter in the following manner: A no. 12 to no. 14 rubber catheter is inserted in the ureter for from 5 to 6.5 cm. and fixed by a few sutures. The point of ablation of the strictured

13. Von Lichtenberg, Alexander: Plastic Surgery of the Renal Pelvis and Ureter, J. A. M. A. **93**:1706 (Nov. 30) 1929.

area of the ureter at the ureteropelvic juncture is then widened and, with long, thin, curved forceps, the catheter is drawn through the lowest calix and the lowest portion of the parenchyma of the kidney. The catheter is fixed with a suture in such a position that it enters the pelvis of the kidney for 2.5 cm. Two lateral openings are previously made in that portion of the catheter which is to lie in the pelvis of the kidney, to insure perfect drainage. The pelvis is then sewed to the ureter in the form of a cuff, and the remaining open pelvis is closed with a few sutures. If the exit of the ureter from the pelvis is congenitally abnormal, the part is excised by a circular incision, the pelvis is closed, and the ureter is reimplanted in correct position lower down. If the radical removal of the obstructing cause is not practicable, ureteropyeloneostomy may be done as a palliative operation. For this von Lichtenberg uses an original method which is allied to the Finney gastroduodenostomy and which has given excellent operative and postoperative results.

Von Lichtenberg presented the results of 80 operations for renal obstruction in patients who were treated over a period of two years. In 41 per cent, the kidney had to be removed because the obstruction was complete. In 47 cases (59 per cent), treatment was conservative. In 23 cases, mechanical obstruction could not be found. In 27 per cent of these cases, the obstruction was of neurogenic origin. In 12 cases, nephrectomy was performed. Fenger's operation was performed in 10 cases. In 1 case, the operation was combined with pyeloplication. Congenital abnormalities were found in 20 cases (25 per cent). Abnormal insertion occurred in 3 cases, hypoplastic kidney in 2 cases and accessory vessels in 15 cases. Nephrectomy was performed in 10 of these cases (50 per cent), a neoimplantation of the ureter was done in 1 case, and dissection of an accessory vessel was done in 9 cases. There were strictures of the ureteropelvic juncture in 37 cases. In 11 cases of ureteropelvic obstruction (30 per cent) nephrectomy was performed; in 9, ureteropyeloneostomy; in 11, Fenger's plastic operation; in 2, neoimplantation, and in 4, surgical dilation of the ureter. Among the 47 cases in which conservative operation was done, secondary nephrectomy was performed in 3 (7 per cent). Death did not occur in any of these cases.

[Ed. Note.—Plastic operations on the ureter and renal pelvis have been gaining in favor both in this country and in Europe during the last few years. Ten years ago such operative procedures sometimes made subsequent nephrectomy necessary, and they were held in bad repute. Recently, the work of Quinby, Young and Walters has offered much promise. Von Lichtenberg's method of ureteral implantation by splinting the site of anastomosis with a catheter which provides urinary drainage through the pelvis of the kidney during the time of healing

seems to be based on sound surgical principles. Furthermore, it is in accord with the experiments on shunting the flow of urine from the site of ureteral anastomosis, which have been described a number of times in American literature during the last two years.]

Quinby [14] stressed the importance of constructive and safe operation when possible. Lack of familiarity with the possibilities of conservation offered by plastic operations on the kidney, ureter and pelvis, or a lack of knowledge of the technic of such operations, is mainly responsible for too many nephrectomies having been performed in the past. In general, the renal conditions which are most frequently amenable to plastic surgery are those in which stasis of urine within the pelvis of the kidney or in the ureter has taken place. A more comprehensive understanding of the dynamics of the ureter with regard to their application to clinical and pathologic phenomena is aiding in the explanation of many instances of apparent stricture or vesical reflux and ureteral retroperistalsis. Normal peristalsis of the ureter is now known to begin in the pelvis of the kidney and is propagated downward to the bladder. It has been demonstrated that hydronephrosis can be caused experimentally by inhibition of peristalsis without any mechanical obstruction of the lumen of the ureter. In other words, the ureter is composed of smooth muscle fibers, and their reaction to many forms of stimuli is known to be extremely labile.

In view of these known facts, Quinby suggested that the cause of the hydronephrosis associated with an abnormality of the blood supply is to be found in the pulsations of the artery itself, lying in juxtaposition to the ureter and inhibiting there the normal flow of peristaltic waves. Mechanical obstruction is not necessary; the current of action set up by each arterial beat is sufficient to cause nervous interference of a minor degree in the ureter.

The pelvis of the kidney dilates slowly and progressively from birth, and finally symptoms appear. Many of these patients date the onset of symptoms at some period during their second ten years of life.

Six patients operated on during the last two years for hydronephrosis convalesced normally. Investigation of 16 cases of plastic operations on the kidney had shown that in every instance the function of the kidney operated on has improved.

[Ed. Note.—For years, Quinby has been most insistent on conservative plastic operations in cases of hydronephrosis and obstructive disease in the kidney and ureter. As a pioneer in this field, his work has been stimulating to those who are following, modifying and sup-

14. Quinby, W. C.: Factors Influencing the Operative Procedure in Hydronephrosis, J. A. M. A. **93**:1709 (Nov. 30) 1929.

plementing his technic. Doubtless great development and simplification of technical procedure will come within the next few years, with the result that fewer radical total nephrectomies will be performed.]

Walters and Braasch [15] reported on 10 plastic operations for hydronephrosis performed on 9 patients at the Mayo Clinic. In 1 of the 4 cases in which a hydronephrotic renal pelvis was resected, the operation was bilateral. Four of these 5 resections were successful; secondary nephrectomy was necessary in the other case. In the case in which resection was bilateral, with an interval of four months between operations, results in both kidneys were excellent. Resection of the hydronephrotic or pyonephrotic portion of a duplicated kidney was performed in 3 cases. Ureteropyeloneostomy for obstruction at the ureteropelvic juncture was done in 2 cases; in 1 of these, the obstruction involved a solitary kidney and was acute and complete; in the other, the obstruction followed pelviolithotomy performed elsewhere.

The value of plastic procedures on the kidney, pelvis and ureter from which the outflow is obstructed is illustrated in 2 of the cases reported by Walters and Braasch in which the plastic operations were necessary. In 1 instance, the hydronephrosis was bilateral with extensive dilatation and considerable infection; in the other, the obstruction of the ureteropelvic juncture was complete and the kidney was solitary. In only 1 of the 9 cases was secondary nephrectomy necessary; in this case the hydronephrotic pelvis was of a capacity of approximately 450 cc., and infection and edema caused obstruction of the ureteropelvic juncture. The decision for resection of the renal pelvis rather than nephrectomy was probably inadvisable because of the extreme degree of hydronephrosis and of obstruction of the renal parenchyma. The other patients recovered; urinary drainage and renal function were satisfactory. Postoperative urographic examination showed that the renal pelves were approximately normal.

[Ed. Note.—This work is in line with that of von Lichtenberg and Quinby and shows a definite trend toward conservative plastic operation in dealing with urinary obstruction. The recent reports of plastic operations on the renal pelvis and ureter show results which are not ideal, but are much better than those obtained a few years ago when such procedure was usually an unintentional preliminary step to nephrectomy. With improvements in technic such plastic operations should gain favor

15. Walters, Waltman; and Braasch, W. F.: Urinary Obstruction and Hydronephrosis, J. A. M. A. **93**:1710 (Nov. 30) 1929.

with urologists in general and thus offer a definite opportunity for saving functioning renal tissue which would otherwise be sacrificed.]

Herbst and Polkey [16] undertook an investigation on dogs to determine the probable value of Fenger's operation for relief of hydronephrosis due to stricture. Failure of the operation was noted in a large percentage of clinical cases; some of the cures reported in the literature were probably only symptomatic, not actual. The operation was uniformly unsuccessful in a series of 16 dogs, due to mechanical buckling at the site of operation and increased scarring which produced obstruction. Herbst and Polkey concluded, therefore, that ureteropyeloplasty is not a reliable method to be used for the relief from hydronephrosis due to stricture at the ureteropelvic juncture, a conclusion that had been borne out by the clinical experience of many who have utilized this method.

Herbst and Polkey expressed the belief that some form of anastomosis between the pelvis and ureter will give better results than plastic procedures in this type of obstruction. Clinical facts pertaining to such anastomoses are limited and a study is being conducted on the dog to determine, if possible, which of the various methods offers the best chance of success.

Patch [17] stated that the increasing tendency toward conservatism in renal surgery is a principle particularly applicable in cases of hydronephrosis associated with aberrant renal vessels, especially of the lower pole. When hydronephrosis exists to a degree of complete or almost complete renal atrophy, nephrectomy is indicated. In cases in which considerable renal tissue remains, treatment should be directed toward relief of the obstructive condition producing stasis, as well as toward conservation of the kidney. Unless obstruction is relieved, further extension of the hydronephrosis and destruction of the kidney will result. Experimental and clinical evidence shows that ligation of a renal vessel is followed by necrosis of the renal tissue supplied by the vessel. In one of Patch's cases in which a small vessel of the lower pole was ligated, the patient died a few months later from intercurrent disease. Examination of the kidney revealed necrosis of the segment of kidney supplied by the ligated vessel. The renal necrosis following ligation is usually aseptic, but secondary suppuration of the infarcted portion of

16. Herbst, R. H., and Polkey, H. J.: Fenger's Uretero-pyelo-plastic Operation: An Experimental Study, J. Urol. **23**:23 (Jan.) 1930.

17. Patch, F. S.: Conservative Plastic Surgery in the Treatment of Hydronephrosis Associated with Aberrant Vessels, Brit. J. Urol. **1**:373 (Dec.) 1929.

the kidney may follow. The practice of ligating an aberrant vessel is not recommended because of the risk of the procedure.

Patch noted 3 cases within the past eighteen months in which aberrant vessels entering the lower pole seemed to be the prime factor in producing hydronephrosis. Section and reimplantation of the ureter in a position out of contact with the vessel and in a position favorable to drainage was done by Gregoire in 1 case and by Quinby in 7 cases without technical difficulty and with apparent success. In Patch's series relief of the obstruction, as well as conservation of the kidney and the arterial supply of considerable segments of the kidneys, was definitely indicated. Nephropexy did not seem desirable. In all 3 cases section was made of the pelvis, and the cut ends were resutured out of contact with the vessel. Making the incision in the pelvis in which the lumen is larger is more advantageous than in the narrow ureter, with the danger of block by edema, or subsequently by stricture. Only ordinary and transient drainage of the wound was instituted. In no instance was there any complication by leakage or infection, and the patients were all relieved of symptoms.

The technical difficulties in performing the operation and in securing primary union were not great. In one case in which ptosis of the kidney was associated with an aberrant artery, nephropexy was not combined with ureteral implantation because of hesitancy to complicate the operation and because it was desirable to test the efficacy of reimplantation. In choosing between nephropexy and ureteral reimplantation, the latter seemed to be the procedure promising the greatest degree of relief to the urinary stasis. In view of the ease and safety of the operation and the experience gained, Patch would not hesitate to combine the two procedures or to carry out other plastic measures designed to decrease the size of the dilated pelvis and to improve urinary drainage.

Ferrer [18] stated that total renal compression is the result of chronic renal obstruction. Partial renal compression, such as that produced by tumors of one pole of the kidney or stones in the kidney, or the minor or major calices, will not by itself produce true hydronephrosis. Bilateral hydronephrosis occurs only when obstruction is in the lower part of the urinary tract. This obstruction reflects back pressure on the pelvis and, if free collateral venous circulation is formed on or around the capsule of the kidney, pressure atrophy will take place in the renal substance, with the formation of atrophic hydronephrosis. When this type of hydronephrosis is established, the atrophy will take the form and shape of the venous arches that surround the superior portion of each renal papilla.

18. Ferrer, J. C.: Renal Compression, J. Urol. **22**:453 (Nov.) 1929.

Stone.—Keyes [19] reported on the results of operations on 6 patients who had only 1 kidney; 5 operations were performed for stone and 1 was performed for acute suppuration. Decapsulation was performed in a case of acute suppurative nephritis, pyelotomy was performed in 1 case, and pyelonephrotomy in 4. None of the stones was large. The patients have survived from a few months to thirteen years. Roentgenograms after operation did not reveal stone. One patient who began to pass stones from five to ten years after the last operation has had 3 operations on a single kidney. Another patient has had 2 operations. The convalescence of these patients did not differ materially from that of similar patients with 2 kidneys. One patient with acute suppurative nephritis was so sick that when she recovered from decapsulation she had no recollection of the day before the operation. After decapsulation, her temperature became normal, and her mind clear. In the cases of stone, operation was done for anuria in 4 cases and for persistent pain in 1 case. At the time of operation the anuria had lasted one, two, four and six days, respectively.

Two special precautions are taken in operating in cases of this type in the hope of minimizing postoperative renal congestion: the pyelotomy incision is left unsutured, and the kidney is decapsulated. There has been no alarming failure of renal function after operation. Keyes attributed the fact that these patients stand operation almost as well as patients with two kidneys to the gentle handling of the kidneys and to a less severe immediate postoperative reaction in already infected kidneys than occurs in operations on normal renal parenchyma.

Walters [20] reported on 43 operations in cases of solitary kidney or ureter at the Mayo Clinic. Thirty-five of these operations were for stone; in 8 cases ureterolithotomy was performed. The operative mortality in the entire group was 14 per cent, whereas the 8 operations on the ureter were done without mortality. The patients who failed to recover had varying degrees of renal insufficiency and infection, and died in uremia. He emphasized the necessity of early operation for the removal of stones in a solitary kidney and ureter before renal infection and decreasing function increase the risk of the operation. The patient should be reexamined at frequent intervals, especially if urinary lithiasis has been a complication.

Tumor.—Judd and Hand [21] reviewed 367 cases of carcinoma of the kidney observed at the Mayo Clinic over a period of twenty-seven

19. Keyes, E. L.: Operation on the Single Kidney, Especially for Stone, J. A. M. A. **94**:152 (Jan. 18) 1930.

20. Walters, Waltman, in discussion on Keyes (footnote 19, p. 155).

21. Judd, E. S., and Hand, J. R.: Hypernephroma, J. Urol. **22**:10 (July) 1929.

years. Two hundred eighty-three of the 312 patients who underwent nephrectomy and 47 of the 55 who were submitted to exploration have been traced.

These carcinomas of the kidney appear as soft, roughly spherical grayish-yellow growths, often hemorrhagic, and associated with tortuous, dilated superficial veins. In the series of 283 cases the carcinomas were confined to the upper pole in 51 cases, to the lower pole in 60, and to the median renal region of the kidney in 39; the entire kidney was involved in 10, and the involvement was not recorded in 123. The capsule was ruptured in 104 of the cases, and the renal veins were involved in 51. Metastasis was observed in 98 cases. Occasionally, significant symptoms did not appear until the tumor was unusually large. The lesion involved the right kidney in 169 cases and the left kidney in 196. In 2 cases the side involved was not stated. One hundred and sixty-one patients noted the first symptom before the age of 50; 203 noted it after 50; the age of 3 was not recorded. The average duration of symptoms and the average postoperative length of life, both of the patients who died and of those living, is less for females than for males, suggesting that malignancy runs a more rapid course in females.

Hematuria was the first symptom in 43.86 per cent of the entire series of 367 cases. Pain was the initial symptom in 37.32 per cent of the cases; a tumor was the first symptom in 13.62 per cent, and weakness was given as the first symptom in 3.26 per cent. Hematuria occurred in 69 per cent, and a tumor was noted in 80 per cent. Chills, fever and night sweats were present in about 10 per cent of the cases, indicating that the patient may have been reacting to a certain degree of pyelonephritis. Pain occurred in more than 80 per cent of the cases. When the tumor was large enough to be palpated, and when it had become fixed, the mortality rate increased. The size of the tumor bears a definite relationship to the postoperative length of life. The immediate risk of the operation is greater if the tumor is large. If the tumors were small the patients lived considerably longer than if they were of moderate size or large.

There was extension to the renal vein in 51 of the cases in which nephrectomy was carried out; 9 of these patients are still living. Judd and Hand concluded that in cases in which the tumor can be removed without too great risk, it should be done in spite of the involvement of the vein and pedicle.

If the tumor is large, the usual posterolateral incision may be enlarged enough to give satisfactory exposure. The skin, fascia and lateral abdominal muscles are cut, and posteriorly the quadratus lumborum and the costovertebral ligament may be divided; this mobilizes

the lower part of the thorax. In many of these cases it may be advantageous to fracture the lower rib by simply retracting it with the hand. The peritoneum is retracted away from the tumor, which usually bulges well forward. Retraction of the peritoneum permits exposure of the vascular pedicle and examination of the regional lymph nodes. As soon as the tumor has been mobilized and lifted away from the perirenal tissue, the exposure is completed. The kidney is generally adherent to the fatty capsule and is covered with large dilated veins. Usually it is advisable to ligate the pedicle and to remove the clamps; if a large mass of tissue is clamped and the tissues are edematous and friable, this is not always safe. In about 10 per cent of the cases it seemed best to leave the clamps on the vascular pedicle for seventy-two to ninety-six hours. Following nephrectomy alone, 3 patients returned because of recurrence in the ureter. Removal of the upper part of the ureter is indicated in all cases of malignant renal neoplasms but its entire removal is not indicated in cases of this type.

Metastasis is common, progresses slowly, and is difficult to recognize. It may not cause trouble until years after the primary focus has been recognized and treated. Metastasis to the lung is most common. Minute foci occur which are not distinguishable in an ordinary roentgen examination of the lungs. Definite metastasis occurred in 70 patients of this series; it was in the lungs in 39; in the liver in 13; in the brain in 5, and in the bones in 11.

Eighteen men and 8 women had lived ten years or more. The average age of the men was 49 years and of the women 48 years at the time of operation. The right kidney was involved in 15 cases and the left in 11. The average duration of symptoms was slightly more than three years before operation. The first symptom in order of frequency was pain in 12 cases, hematuria in 9, and tumor in 2. A palpable tumor was demonstrated at the time of operation in 11 cases. The tumor was reported as large in 13 cases. The longest length of life after operation for alveolar carcinoma in the series was six years and ten months, and after operation for hypernephroma, twenty-two years and eight months.

Judd and Hand concluded that carcinoma of the renal cortex is extremely malignant and often is well advanced before symptoms are noticeable. Alveolar carcinoma is the most highly malignant of the various types of renal carcinoma, whereas adenocarcinoma is less malignant, judging from the clinical course. Because 106 of the patients of their series lived from three to twenty-two years, Judd and Hand are of the opinion that operation will result in cure in a definite proportion of cases.

[Ed. Note.—This study bears out contemporary concepts of renal neoplasia so far as relative malignancy of sarcoma, carcinoma and

hypernephroid types of renal tumors is concerned. The fact that surgical treatment of 367 cases resulted in prolonging the life of 106 patients affords a hopeful outlook. The use of radiotherapy, either preoperatively or postoperatively, is not mentioned. The fact seems well established that as yet in this field of neoplasia little may be expected of such physical agents.]

Kukudschanow,[22] in studying renal parenchyma in association with tumorous conditions, noted that the changes may vary within wide limits, but usually it remains unchanged. The pathologic-anatomic changes in the kidney are about 60 per cent nephrotic and 50 per cent interstitial. Only rarely is the entire kidney affected, the condition usually being local. The changes are commonly noted in the cortex. Sclerosis of the vessels is frequently noted (70 to 75 per cent). Focal conditions of a nephrotic nature may occur (20 per cent). Functional disturbances of the kidney are absent, or, if present, are only moderate. There is no connection between the size of the tumor and the severity of parenchymal changes. In cases in which only a sixth to an eighth of the parenchyma of the kidney remains, there is severe parenchymal change. The parenchyma not affected by the tumor may be disturbed by pressure of the tumor, stasis of blood, retention of urine or by the toxic products of the tumor. These factors may occur one or more at the same time, whereas in the later stages they may be superimposed on one another.

Schmidt [23] reported on a series of 71 cases of tumor of the kidney. Twenty-three of these cases were not considered because operation had been performed elsewhere or a histologic examination was not made. Of the remaining 48 cases of tumor, 3 were benign and 45 malignant. The tumors comprised 6.14 per cent of all diseases of the kidney in which treatment has been given. The benign tumors were papilloma of the renal pelvis, papillary adenoma of the kidney and papillary cystadenoma of the mucous membrane. The malignant tumors consisted of 29 hypernephromas, 6 carcinomas, 1 papillary carcinoma of the pelvis of the kidney, 3 renal sarcomas, 1 suprarenal sarcoma and 5 congenital mixed tumors in children. From an analysis of this material it was concluded that neither the duration nor the frequency of the classic symptoms, such as palpable tumor, hematuria and pain, was any criterion of the growth or spread of the tumors. Neither were the operative data an indication as to prognosis. The size or

22. Kukudschanow, N. J.: Die Veränderungen der Niere in der weiteren Umgebung der Affektionsstelle bei Nierengeschwülsten, Ztschr. f. urol. Chir. **27**: 337 (July) 1929.

23. Schmidt, A.: Der Wert der klassischen Nierentumorsymptome für die Frühdiagnose, Beitr. z. klin. Chir. **145**:48 (June) 1928.

malignancy of the individual tumors might indicate some idea as to expectancy of life. Schmidt does not believe that cardinal symptoms are necessary for diagnosis and when present usually indicate an extensive growth. A cystoscopic examination was made in 70 per cent of the cases. In 29 per cent of the cases the bleeding side was noted directly. In 73 per cent of the cases renal function, as determined by return of indigocarmine, aided in indicating the affected side. In 10 cases pyelography gave diagnostic aid. Pneumoradiography, according to Rosenstein, gave excellent service in doubtful cases, such as in distinguishing between a renal tumor and spleen.

Tuberculosis.—Medlar [24] expressed disagreement with the two prevalent ideas that excretory bacilluria exists without tuberculous lesions in the kidney and that tuberculosis of the kidney never heals. All obtainable evidence points to the fact that renal tuberculosis is a hematogenous infection and that it is but one manifestation of general tuberculosis. In some cases the major tuberculous lesion occurs in the kidney. From a study of the urine of animals experimentally infected with bacilli of tuberculosis, evidence was not found to support the view that the kidney excreted the bacilli without tuberculous lesions of the ulcerative type being present in the organ. When bacilli of tuberculosis were demonstrated in the urine, ulcerative tuberculous lesions in the kidney were present. The conclusions were that the bacilli were not excreted by noninfected kidneys and that their absence in the urine did not necessarily eliminate the presence of tuberculous lesions in the kidneys.

In the investigation of the healing of tuberculous lesions in the kidney, 30 cases in which death occurred from pulmonary tuberculosis were studied, emphasis being placed on cases in which lesions were small rather than on those that were large and were noted late in the course of the disease. It was found that the kidneys are commonly involved in fatal cases of pulmonary tuberculosis. The renal lesions are hematogenous in origin, and both kidneys are usually involved, although one may be more extensively involved than the other. Scars were demonstrated in a considerable proportion of those kidneys in which definite tuberculous lesions were also present. These probably represent healed tuberculous lesions, although there is nothing pathognomonic of their having been tuberculous. Medlar expressed the belief that a kidney with a large tuberculous lesion will completely heal and that it is possible for it to become less active and regress in its progressive character.

[ED. NOTE.—For many years the contention that healing never occurs in renal tuberculosis has been accepted as axiomatic. Sporadic

24. Medlar, E. M.: The Pathogenesis of Renal Tuberculosis, Am. J. Surg. **7**:605 (Nov.) 1929.

reports of healed tubercle in the kidney have been received with skepticism. Recently the work of Thomas and others has thrown some doubt on the matter. Hence Medlar's observations in cases of pulmonary tuberculosis coming to necropsy are in line with the later conception of the possibility of healed renal tuberculous disease. From the practical point of view, it is still likely that the practice of most urologists will be nephrectomy in unilateral renal tuberculosis, if the process is at all advanced. Certainly such patients if treated surgically or otherwise should have at once the advantages of treatment in a sanatorium. If the disease is bilateral, the indications for operation are more limited. In very early unilateral disease, conservative medical treatment should be employed only if the patient is under frequent observation by a urologist and is being treated under sanatorium conditions.]

Olsen [25] stated that renal tuberculosis and associated renal lesions is not uncommon; some of the coexisting lesions cited were true renal stones, leukoplakia of the renal pelvis, solitary cyst of the kidney and adenocarcinoma. To avoid classification of all the symptoms under one disease, a careful, complete preoperative urologic investigation, together with thorough pathologic studies, is urged.

Thomas,[26] in a recent review, observed that from 25 to 35 per cent of all nephrectomies are done because of renal infection caused by the bacillus of tuberculosis. Forty per cent of such patients are not cured by nephrectomy but continue to have persistent symptoms referable to the bladder, the condition for which many are seeking relief.

Certain pathologic types are recognizable: (1) in toxic albuminuria without casts, few if any pus cells in the urine, and if ulceration occurs it may contain bacilli of tuberculosis; (2) in subacute and chronic nephritis albumin and casts in the urine; bacilli of tuberculosis may be present and pus cells frequently are present; (3) hemorrhagic nephritis characterized by blood cells in the urine, light albuminuria and a few casts, and (4) amyloid degeneration, a type glomerulonephrosis which is possibly the result of inflammatory reaction in the kidney caused by the bacillus of tuberculosis directly, or by toxemia caused by tuberculous infection elsewhere.

In the majority of cases, renal tuberculosis is a bilateral condition. Repeated examinations are necessary to prove the presence of a nondestructive tuberculous infection in an apparently sound kidney. One infected kidney should not be removed until it has been proved conclusively that the other does not contain a destructive lesion. Non-

25. Olsen, Sidney: Associated Renal Pathology in Renal Tuberculosis, J. Urol. **23**:81 (Jan.) 1930.

26. Thomas, G. J.: Renal Tuberculosis, J. A. M. A. **94**:229 (Jan. 25) 1930.

destructive lesions will heal, and the patient with this type of lesion should have the advantage of treatment in a sanatorium to assist him in building up resistance against tuberculosis. Nephrectomy is not the sole treatment for renal tuberculosis. After operation, the patient should be kept in a sanatorium until no evidence of active tuberculosis can be found, urinary or otherwise.

Braasch [27] stated that the diagnosis of early renal tuberculosis is frequently made only after repeated inoculation of guinea-pigs or long study of the case, and the condition may easily be overlooked if only the usual clinical methods are employed. Pyelography will often demonstrate deformity in such cases, which is not apparent by other methods. Inoculation of guinea-pigs, as well as renal functional tests, are uncertain in their results. When the diagnosis is in doubt urography offers the most valuable aid. One of the greatest difficulties in the study of renal tuberculosis is to determine whether the disease is unilateral or bilateral. It has been shown recently that the results of inoculation of guinea-pigs with material from a healthy kidney is frequently positive, as the result of regurgitation of bacilli of tuberculosis from the bladder.

Frisch [28] stated that the diagnosis of urinary tuberculosis does not offer special difficulties unless organisms are found other than bacilli of tuberculosis. Formerly sterile pyuria was assumed to be pathognomonic of tuberculosis. It is only recently that the rôle of mixed infections has been considered. Wildbolz noted mixed infections in 22 per cent of his cases of renal tuberculosis; Runeberg noted it in 37 per cent of 2,655 cases; Suter noted 8 cases in 78; Pousson, 12 in 32, and Rafin, 71 in 239.

Colombino demonstrated that in tuberculosis of the urogenital tract the leukocytes exhibit characteristic changes. In an untreated preparation of the urine, there may be seen elongated, dented or jagged forms; occasionally there may be oval protoplasmic bodies, which come from the leukocytes. After staining, many vacuoles are found about the nucleus, and the protoplasm shows marked shrinkage. If leukocytes thus formed are found in conjunction with erythrocytes, it is fairly certain that tuberculosis is present. Frisch stated that this phenomenon was present in all of his ten cases. Bacteriologic examination of the sterile urines revealed the colon bacillus in 5 cases, streptococcus in 2 cases, and staphylococcus in 3 cases. In 1 case the bacillus could not be demonstrated preoperatively. The source of these secondary infections is not known.

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27. Braasch, W. F., in discussion on Thomas (footnote 26, p. 238).

28. Frisch, Bruno: Ueber Mischinfektion bei Nierentuberkulose, Ztschr. f. urol. Chir. **27**:248 (May) 1929.

Perinephritic Abscess.—Feci [29] noted that perirenal abscess or perinephritic phlegmon may occur in the acute, subacute or chronic form. The chronic form is the more common and the most difficult to diagnose. He is of the opinion that roentgen examination may yield significant data in regard to the diagnosis. The abscess cavities were injected with a substance opaque to the roentgen rays. These data, linked with the clinical symptoms, permitted him to make a correct diagnosis in 2 cases.

29. Feci, Lorenzo: Contributo radiologico alla diagnosi degli ascessi perirenali, Arch. ital. di urol. **4**:503 (Aug.) 1928.

(To be Continued)